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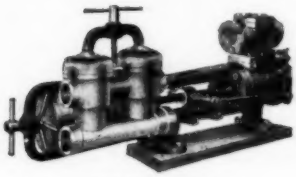

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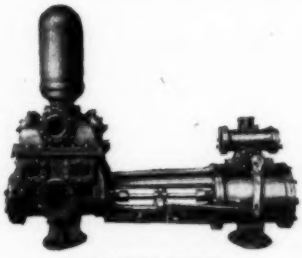

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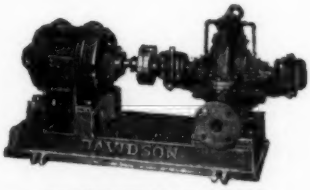

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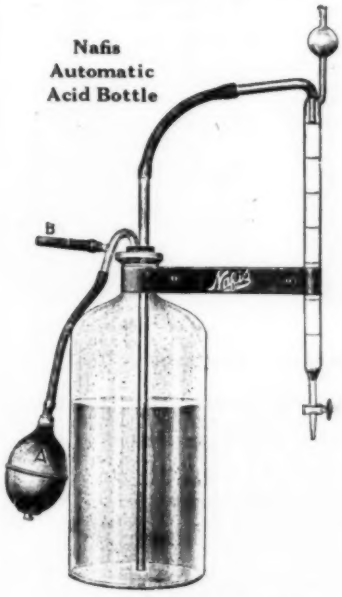

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A TEST FOR DETERMINING THE CHARACTER OF THE CURD FROM COWS' MILK AND ITS APPLICATION TO THE STUDY OF CURD VARIANCE AS AN INDEX TO THE FOOD VALUE OF MILK FOR INFANTS[1]

REUBEN L. HILL

Utah Agricultural Experiment Station, Logan, Utah

Received for publication August 10, 1923

INTRODUCTION

Great difficulty has been experienced in adapting cows' milk to the needs of very young infants and also in its use by older infants at weaning time. Usually the transition period from mothers' to cows' milk is accompanied by little or no gain in weight by the child and often results in a loss.

Some of the more delicate infants die as a result of the lack of a food that they can properly digest and assimilate. Considerable difficulty is experienced by most infants in digesting the curd of cows' milk which has a comparatively tough, hard texture differing from the fine feathery appearance of mothers' milk. To so modify the milk as to render the curd more digestible by infants is one of the big problems of infant feeding. Most babies will make good gains on a milk that can be properly digested irrespective of the animal from which it is obtained.

Physicians often recommend mixed herd milk in preference to individual cows' milk. This is usually a wise recommendation, but if the milk from some of the cows is shown to be more digestible than that of the rest of the herd it would be desirable to use this milk in preference to mixed herd milk.

Often various milks and milk substitutes are experimented with until finally a milk or other substitute is found upon which

[1] Studies on the curd test were begun by the author while at the Maryland Agricultural Experiment Station where considerable data were obtained by the use of the test in its original form. The test in its present form and all results used in this publication were developed at the Utah Agricultural Experiment Station.

the infant makes gain. One purpose of this test is to determine, if possible, in advance the adaptability of the milk for the infant as well as in aiding in the elimination from the special baby milks of the milk shown to be hard-curded. The results to date have been very encouraging. Infants have made constant and consistent gains on the milk shown to be soft-curded by the test even immediately after weaning. In some cases a change from the soft-curded to the mixed herd milk has completely upset the infant which was soon restored to normal by a return to the soft-curded milk. The data collected to date are insufficient to warrant any positive statement as to the practical value of the test. However, the feeding of the soft-curded milk has given very favorable results.

DETAILS OF THE MANIPULATION OF THE TEST

The curd knife. For determining the hardness of the curd a star-shaped, 10-pronged curd knife is used. This knife has a $\frac{3}{8}$-inch center which is tapered at 60° to fit over a $\frac{1}{4}$-inch stem. The stem is used as the handle and is $6\frac{1}{4}$-inches long before it is bent to form the $\frac{1}{4}$-inch loop in the end. Into the ten $\frac{1}{8}$- by $\frac{1}{20}$-inch slits in the center the ten blades are soldered. The blades are cut from $\frac{1}{20}$-inch sheet brass and are $\frac{1}{8}$-inch wide and all are sharpened to a knife edge. Each blade is cut twice the length needed for the knife blade. It is then placed in a bending jig and bent at an angle of 36°. Five blades thus bent are soldered into the center core to furnish the ten blades. The knives when completed weigh on the average 17.5 grams and should not vary in weight more than 0.5 gram (see fig. 1).

The spring balance. For measuring the tension required to draw the curd knife through the curd a specially constructed spring balance with a capacity of 200 grams and a sensitivity of 0.5 gram is used. This balance was manufactured for the experiment by John Cataillon and Sons of New York.

The coagulation cylinders. The 8-ounce screw-capped jars manufactured by the Whitall Tatum Company are used for containers for the milk to be tested. The jars should be examined for uniformity before use.

The coagulant. For coagulating the milk a pepsin-calcium-chloride mixture is used. Marked differences can be obtained by the use of pepsin alone. The use of calcium chloride, however, increases the variation and decreases the coagulation time and gives a more uniform coagulation. The coagulant consists of a mixture of three parts of a 0.6 per cent solution of Eimer and Amend's 1 to 3000 scale pepsin to 1 part of a saturated solution of calcium chloride.

FIG. 1. THE CURD KNIFE

METHOD OF PROCEDURE

The milk should be tested as soon as possible after it is drawn from the cow, as a marked increase in acidity will alter the test. When comparative results are to be obtained it should be held at a constant temperature and tested the same length of time after milking. Duplicate 100 cc. samples of thoroughly mixed milk are placed in the glass jars previously described. The

jars are then immersed in a water bath and the temperature of the milk brought up to 35°C. They should be maintained at this temperature throughout the test. After placing the curd knives in the jars, 10 cc. of freshly mixed coagulant are added

FIG. 2. THE SPRING BALANCE

by means of a very rapidly flowing pipette. It is sometimes necessary to enlarge the opening in the pipette to allow a more rapid flow. The jar should be agitated to give the milk a circular motion while the coagulant is being added, thus assuring a more even mixture of the coagulant. The amount and uni-

formity of the agitation given the jars during the addition of the coagulant is very important. Too rapid or prolonged agitation will agglutinate the curd, while little or no agitation will not adequately mix the coagulant with the milk resulting in an uneven coagulation. The author adds the coagulant with a pipette held in the left hand while the jar is agitated with the right. By a little practice a uniform and smooth motion can be obtained.

After adding the coagulant the jar should be returned to the water-bath, care being taken not to agitate the same for a period of ten minutes when the spring balance is hooked through the loop in the curd knife and by a slow and even tension the knife is drawn through the curd. The amount of tension required can be read directly on the balance. Deducting the weight of the curd knife will give the net tension required. It is very essential that the spring balance be held directly above the curd knife with a perpendicular slope; otherwise, friction of the plunger on the sides or back of the scales will render the test inaccurate.

By using a large number of knives one can run duplicate samples on from 15 to 20 cows at one time. If it is used immediately, coagulant for 40 or more samples can be mixed before starting. The pepsin deteriorates, however, if violently agitated or if it is allowed to stand too long in the calcium-chloride solution.

When one becomes experienced with the method duplicate samples will check under his manipulation to within about 5 grams. Some may vary as much as 10 grams, while most samples check almost exactly. The variation between the hard- and soft-curded milks is so great as to overcome slight variations in samples.

NORMAL VARIATION IN THE CURD CHARACTER OF COWS' MILK

The normal variation in the curd character of the milk from the cows of the Utah Agricultural College dairy herd is shown for a period of six months by curves in figures 3 and 4. Figure

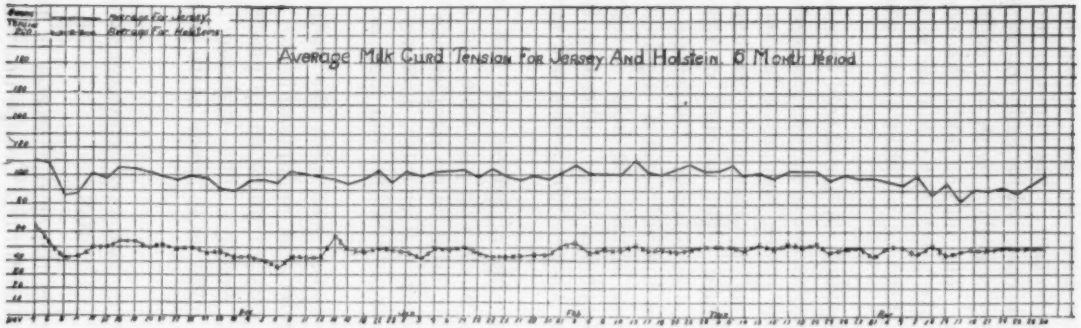

FIG. 3. CURVE SHOWING GRAMS OF MILK CURD TENSION OF JERSEY AND HOLSTEIN AVERAGES FOR THE ENTIRE HERD OF 25 COWS OF THE UTAH AGRICULTURAL COLLEGE DAIRY HERD FOR A SIX-MONTH PERIOD

Perpendicular figures indicate grams of milk curd tension. Horizontal figures indicate date on which test was made.

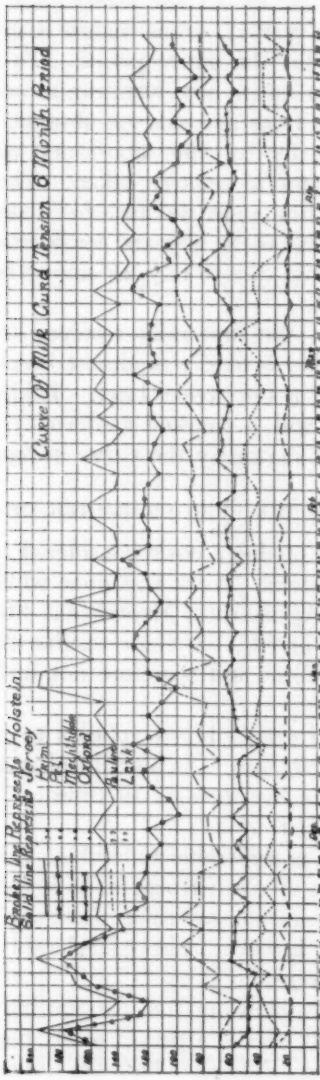

FIG. 4. CURVE SHOWING GRAMS OF MILK CURD TENSION OF SIX TYPICAL COWS FROM THE UTAH AGRICULTURAL COLLEGE DAIRY HERD FOR A SIX-MONTH PERIOD

Perpendicular figures indicate grams of milk curd tension. Horizontal figures indicate date on which test was made.

3 shows the average test of all the Jerseys and all the Holsteins for a six-month period, while figure 4 gives the curd test on 6 typical cows for the entire period. To obtain these curves the samples of the entire herd were run at one time under as nearly identical conditions as could be obtained. The samples were taken personally by the laboratory assistant who placed them in cold water as soon as taken. They were held at about 15°C. until they were warmed for coagulation. In spite of these precautions there appears considerable variation in the curd character from day to day, as can be seen from the curve shown in figure 4.

It was observed that the first milk received from the cow after the colostrum period is over was almost invariably harder than the milk obtained a few weeks later. Taking the entire lactation period there was a marked uniformity in the curd character. This is well shown by the curve in figure 3.

EFFECT OF BREED ON THE CURD CHARACTER OF THE MILK

The only two breeds of dairy cows considered in this paper are the Jersey and Holstein. Work was done while the author was at the Maryland Agricultural Experiment Station on the Guernsey and Ayrshire breeds, but these results were before the test was in its present form and therefore not included in this report.

As a general rule the Jersey breed appears to have a much harder curd than the Holstein. The amount of tension required to cut the curd in some instances is 10 times as great in the Jersey as with the Holstein milk.

There is, however, a considerable individual variance within the breed and the milk of some Holsteins is invariably harder than the milk obtained from some of softer Jerseys. The average for the Holstein cows, however, was considerably lower than the average for the Jerseys.

The curve in figure 3, showing the average hardness of the Jersey and Holstein milk, is for a period of six months and indicates the almost uniform difference between the curd character of the two milks. The curve in figure 4 shows the curd variance

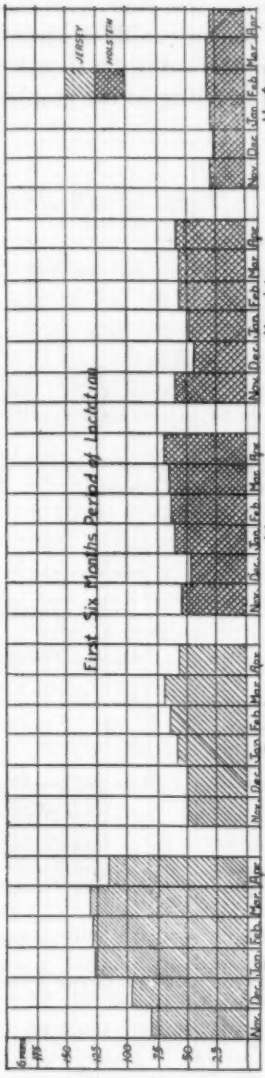

FIG. 5. GRAPH SHOWING EFFECT OF PERIOD OF LACTATION ON THE MILK CURD TENSION USING TYPICAL COWS FROM THE UTAH AGRICULTURAL COLLEGE DAIRY HERD IN THE FIRST SIX-MONTH PERIOD OF LACTATION

of some selected cows from the Holsteins and Jerseys. From this curve it can be seen that the milk of Mechtilda, a Holstein, was invariably harder for the entire six-month period than that of Oxford, a Jersey. By referring to the graphs shown in figures

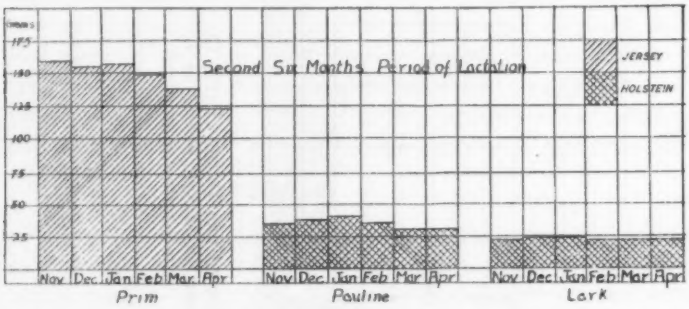

FIG. 6. GRAPH OF THE MILK CURD TENSION OF COWS IN THE SECOND SIX-MONTH PERIOD OF LACTATION

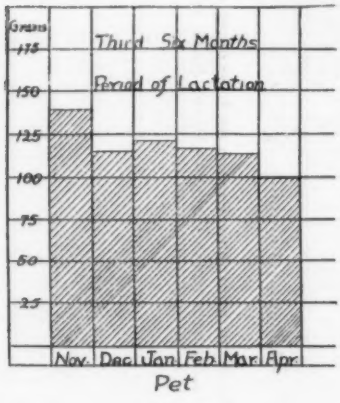

FIG. 7

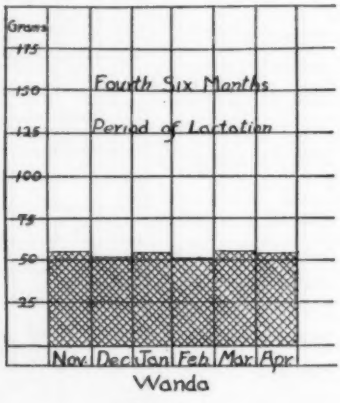

FIG. 8

FIG. 7. GRAPH OF MILK CURD TENSION OF COW IN THE THIRD SIX-MONTH PERIOD OF LACTATION

Note the gradual decrease in tension.

FIG. 8. GRAPH OF THE MILK CURD TENSION OF A HOLSTEIN COW IN THE FOURTH SIX-MONTH PERIOD OF LACTATION

5, 6, 7, and 8 the curd variance for this six-month period is graphically indicated. From these, the extreme variance in curd texture between Lark, the softest Holstein, and Prim, the hardest Jersey, can be seen as well as the greater variability in milks of the harder curded cows.

THE PERIOD OF LACTATION AS AFFECTING THE CURD CHARACTER OF THE MILK

At the present writing the author is unable to supply results of the curd character for an entire lactation period on the same cow. Beginning with October 1922 the Utah Agricultural College dairy herd was classified according to the lactation period of the cow. Some cows had just freshened, while others had been lactating six, twelve, and eighteen months. The curd variance of the milk of cows in the first, second, third, and fourth six-month period of lactation all taken during the same period is shown by these graphs in which a slight increase in hardness of the curd is apparent. This increase was neither uniform nor universal. The milk of Hartog, one of the softest curded Holsteins, decreased in hardness for this period, while that of Foxy, a Jersey, showed a large but uneven increase.

For the second six-month period graphs of but 3 cows are shown. Of these, Prim, the hardest curded Jersey, decreased in milk curd tension about 27 per cent. This decrease was not uniform, yet it exhibits a greater degree of uniformity than most of the graphs. Pauline and Lark, the other 2 cows in this period, are two of the softest curded Holsteins and their milk is used as special baby milk. During the six-month period Pauline showed slight decreases and increases in the curd tension of her milk, while the milk of Lark remained remarkably constant and uniformly soft for the entire period.

Only 1 Jersey was in her third six-month period of lactation, having calved a year prior to the commencing of the experiment. This cow, Pet, shows an irregular but decided decrease in milk curd tension for the period. At the beginning of the experiment 1 cow, Wanda, a Holstein, had been milked eighteen

months. Her remarkably uniform record is shown in the graph of figure 8.

Summarizing these results, there seems to be a tendency for a cow to increase in curd tension of her milk for the first half of a normal lactation period and then gradually decrease for the remainder of the period. This is not a uniform rule. Any udder inflammation or infection has a tendency to harden the curd of the milk. A decided change in curd tension was also observed when the cows were "in heat", which in part explains some of the irregularities in the curve of their milk tension.

INFLUENCE OF THE FAT CONTENT UPON THE CURD CHARACTER OF THE MILK

The fact that the average curd tension of the Jerseys was higher than that of the Holsteins may lead some to conclude that the fat content was a limiting factor in curd tension. Our results, however, show that the curd tension is independent and apparently in no way related to the fat content of the milk. To test this still further large samples of the milk from 12 cows —6 Jerseys and 6 Holsteins—were taken. A small sample was set aside and run for curd tension according to the usual method. The rest of the milk from each cow was separated separately in a very small Viking separator. The separator was washed between each sample and the first milk separated from each sample discarded. The curd test was then made on the skimmed milk of each cow. The results of these tests are shown in table 1 and the graphs of figures 9, 10, and 11.

From the table and graphs it is evident that the curd tension was increased by the removal of the fat from the milk and also that there was no direct correlation between the fat content of the milk and the curd tension. By comparing figures 10 and 11 the remarkable uniformity in the results of April 10 and 21 can be seen. In general, the larger the fat content the greater the increase in the curd tension as a result of its removal, its presence serving to soften the curd of the milk. This may account for the fact that sometimes infants that cannot digest the mixed milk do well on "top milk".

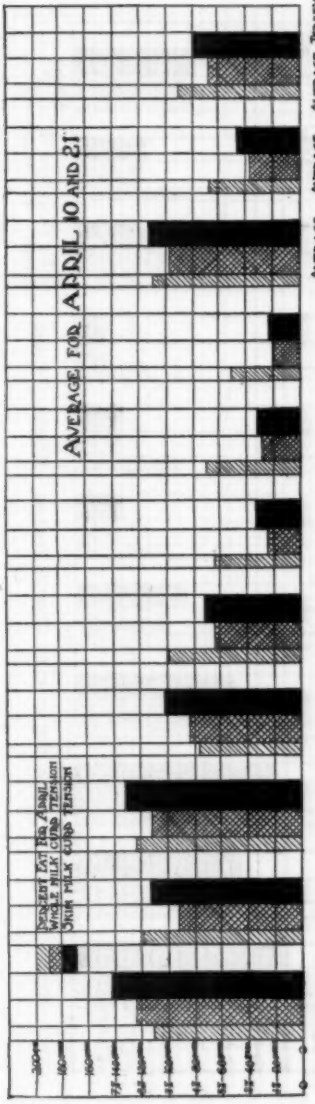

FIG. 9. GRAPH OF AVERAGE MILK CURD TENSION BEFORE AND AFTER REMOVAL OF THE FAT OF JERSEY AND HOLSTEIN COWS

Note the uniformity in graph, figures 9, 10, and 11

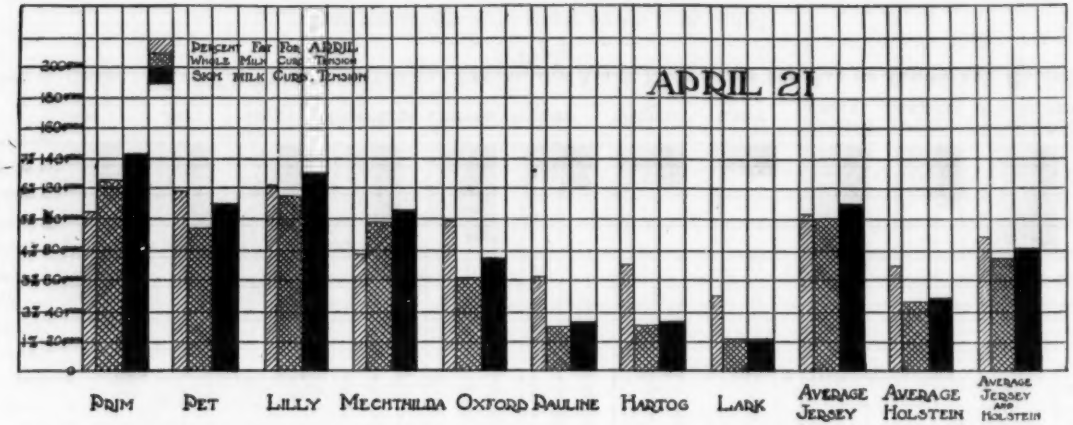

FIG. 10. GRAPH SHOWING EFFECT OF REMOVAL OF FAT CONTENT OF MILK ON THE MILK CURD TENSION OF JERSEY AND HOLSTEIN COWS FROM THE UTAH AGRICULTURAL COLLEGE DAIRY HERD ON APRIL 21, 1923

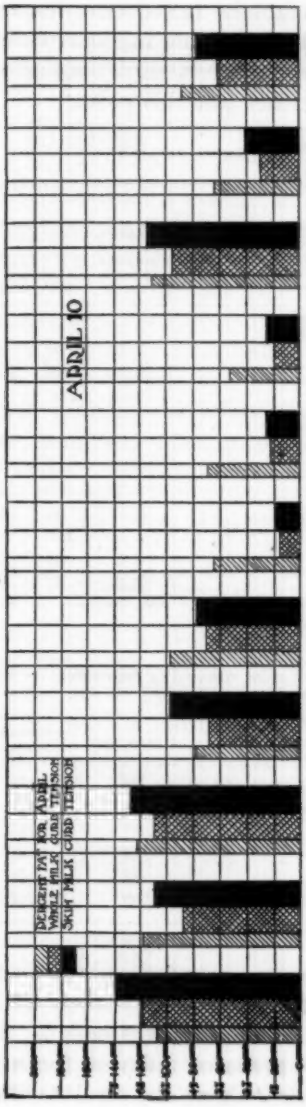

FIG. 11. GRAPH OF THE MILK CURD TENSION OF JERSEY AND HOLSTEIN COWS BEFORE AND AFTER REMOVAL OF FAT ON APRIL 10, 1923

Since the objection might be raised that the removal of the "slime" from the milk in separation might remove constituents other than fat which would effect curd tension a later experiment was outlined to further test this point.

TABLE 1

Curd tension of milk before and after removal of the fat content of the same

NAME OF COW	AVERAGE PER CENT OF FAT IN MILK	CURD TENSION ON APRIL 10		CURD TENSION ON APRIL 21	
		Whole milk	Skim milk	Whole milk	Skim milk
Hartog	3.5	22	25	30	33
Lark	2.7	19	23	22	22
Lilly	6.1	109	132	117	131
Mechthilda	3.8	67	98	99	104
Nemo	6.2	87	103	86	91
Oxford	5.0	65	68	63	75
Pauline	3.2	17	18	33	35
Pet	5.9	88	111	95	113
Pontiac	3.8	54	57	52	62
Prim	5.3	118	140	127	143
Rachel	3.5	51	64	48	59
Rill	4.5	62	67	62	73

TABLE 2

Curd tension of milk before and after removal of fat content as well as on re-mixed fat and milk

NAME OF COW	WHOLE MILK	PREPARED MILK	SKIM MILK
Lark	24	20	24
Lilly	118	106	139
Mechthilda	87	87	122
Oxford	61	66	88
Pauline	48	50	62
Rill	62	56	73

The samples of milk were separated as before and the amount of cream required to bring up the fat content of the skim milk to that of the original whole milk was added. The curd tests were then made on this prepared milk, on the whole milk, and on the skim milk. Table 2 shows the results obtained.

From this table it is evident that the removal of fat content from the milk is responsible for hardening the curd since the remixed milk checked with the milk before separation.

IS CURD CHARACTER OF THE MILK A TRANSMITTED CHARACTERISTIC?

Whether or not the curd character of the milk is a transmitted characteristic can not at this writing be definitely shown. Our results with 3 cows, however, would indicate that it was transmissible. From the graphs one can see that the milk from Hartog and her 2 daughters, Pauline and Lark, was softer in curd than any of the other milks. About eight years ago Hartog's mother's milk was used to feed a delicate infant with splendid results. This would indicate that the curd characteristic had been transmitted for two generations. It may be possible to breed for softness of curd in milk with success.

THE CAUSE OF CURD VARIANCE IN COWS' MILK

Work is now being done on the reason for this wide variance in cows' milk. It may be due to a variation in the mineral content. That there is a wide variance in the mineral content of cows' milk has been shown by recent investigators. An increase in the sodium or potassium salts of the milk would have a tendency to soften the curd, while conversely a decrease in the soluble calcium salts would produce a like result. Work is now in progress on the calcium content of the milk, but the results so far would not warrant a positive statement regarding the relation of calcium content of milk to curd texture.

PRACTICAL APPLICATION OF CURD TEST

The results thus far obtained would indicate that this test may find practical application in selecting those cows giving milk especially adapted to the needs of infants and invalids. It is planned to test several dairy herds in the state and collect data on the use of these special soft-curded baby milks on the nutrition of infants. It is also possible that the harder curded

milks will be superior for cheese-making. The extent to which the curd character of the milk can be influenced by a variation in the feed of the cows is also being checked by this test.

SUMMARY

A curd test has been developed whereby the degree of hardness of the curd of cows' milk can be determined. By means of this test the dairy herd of the Utah Agricultural College has been classified on the basis of the curd character of the milk. This classification extends over a period of more than six months and includes cows in all stages of lactation.

As a result of these studies it has been shown that each cow had an individual milk curd character that was fairly regular throughout her entire lactation period, but in general it hardened during the first part of the period to soften again toward the latter end of the normal lactation period. The curd tension of the harder curded milk was sometimes as much as 10 times as great as the curd tension of the softer curded milk.

The individual difference in curd character was independent of breed and fat content of the milk. The Jersey breed as an average, however, had a much harder curded milk than the Holstein breed, yet some of the Jerseys had a softer curded milk than the harder curded Holsteins.

ACKNOWLEDGEMENTS

The author desires to express his appreciation to Prof. William Peterson, Director of the Utah Agricultural Experiment Station, for advice and encouragement as well as to Dr. F. S. Harris, former Director of the Utah Agricultural Experiment Station, for his interest and counsel. The author further wishes to express his indebtedness to Miss Blanche Cooper and Mr. Angus M. Maughan for their aid in analytical work on the mineral content of the milk and to Mr. Alwyn Sessions for running curd tests and collecting samples.

HOW THE ADVANCE OF THE PERIOD OF LACTATION AFFECTS THE MILK FLOW

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Upon calving, the rate of milk secretion of the dairy cow gradually increases for a time and then gradually decreases until the animals become dry. The cause of the gradual increase in the flow of the milk after calving is undoubtedly due to the improving condition of the animal following parturition, increasing consumption of food, and to the gradual perfection of the mammary gland.

The object of this paper is to present data on the time of maximum production and to show that the percentage decline of milk secretion with the advance of the stage of lactation is constant.

I. TIME OF MAXIMUM MILK PRODUCTION

It is well known that maximum milk production is usually reached during the first or second month of lactation, but a search of the literature failed to show when the exact peak is reached. Haecker (1) of the Nebraska Station found that nine-tenths of the cows whose records were studied made their best records during the first ten weeks.

In order to obtain further information on this problem 80 Holstein-Friesian records from the dairy herd of the University of Missouri were selected and the average daily milk production for the first ninety days determined. As milk production is notably affected by pasture, heat, flies, etc., during the summer months, only those records were chosen which came entirely between September 1 and May 1. Neither the age of the animals nor their condition at calving time were considered.

The records were divided as to the number of milkings per day. Of the 80 records studied 40 were those of cows milked twice

per day, 32 of cows milked three times per day, and 8 of cows milked four times per day.

The results are presented in figure 1. It will be seen that the cows milked twice per day reach their peak of production on the fifteenth and sixteenth days after calving. The cows milked

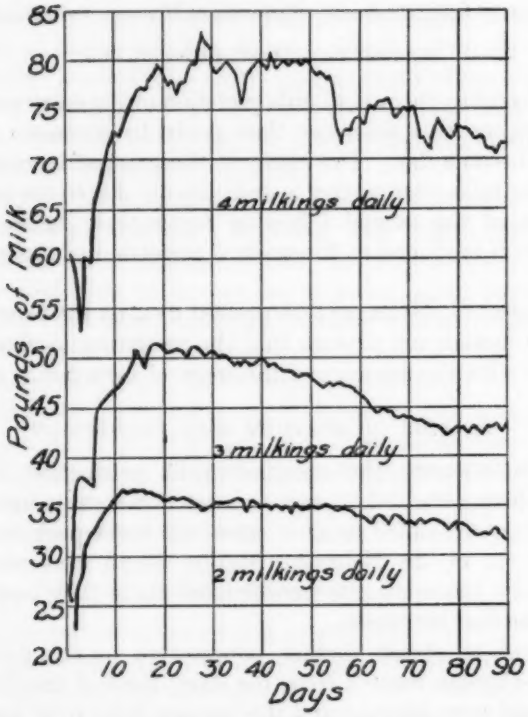

FIG. 1. THE TIME OF MAXIMUM MILK PRODUCTION OF HOLSTEIN-FRIESIAN COWS

three times per day reach a peak on the eighteenth day while the cows milked four times per day did not reach their maximum production until the twenty-eighth day after calving.

It appears from this that the frequency of milking and the amount of milk produced are the most important factors in governing the time of maximum milk production. This may be

explained as being due to the length of time necessary to get a high producing cow upon full feed.

II. THE DECLINE OF MILK PRODUCTION

The decline of milk secretion after reaching maximum production is well known to be fairly uniform. The length of lactation period, however, varies with the individual animal, the feeding and management, the time of breeding, and certain hereditary qualities. Highly developed dairy cows if left farrow will often continue to produce milk for several years, while beef cows and animals of inferior dairy qualities will dry up within a few months even when furnished with an abundance of feed.

In previous studies (2) (3) on the effect of the stage of lactation on the milk yield, where the percentage was based on the production of the previous month, more or less irregular decreases have been found. It has never been shown, however, that there was any definite way in which milk production decreased from month to month during the lactation period irrespective of breed or the amount of milk produced by the animal.

From a physiological standpoint it seems reasonable that so important a function as milk secretion must be regulated in some definite way when an abundant food supply is available. In connection with other studies being made, a large amount of data showing the monthly declines in milk production was available. This data was studied to determine if there was any regularity in the way milk secretion declined from month to month during the lactation period.

We have found that there is indeed such a regularity or law governing the decline of milk secretion with advance of the period of lactation. This law may be expressed by saying that each months production after the second month is a constant percentage of the preceding months production. In the case of farrow Guernsey cows, where the factor of pregnancy is eliminated, each months production is about 94 per cent of the preceding months production. This idea may be expressed mathematically by the equation

$$M_t = M_o e^{-kt}$$

where M_t is the milk produced during any month of the lactation period t. M_o is the initial theoretical production and k is the persistency constant while e is the base of natural logarithms.[1]

TABLE 1

Decline of milk secretion with the advance of the period of lactation

MONTH OF LACTATION	(1) GUERNSEY COWS, AVERAGE 3215 LACTATION PERIODS		(2) GUERNSEY COWS, AVERAGE 900 LACTATION PERIODS		(3) GUERNSEY COWS, AVERAGE 370 LACTATION PERIODS		(4) ALL BREEDS, AVERAGE 1143 LACTATION PERIODS		(5) JERSEY COWS, AVERAGE 305 LACTATION PERIODS		(6) HOLSTEIN COWS, AVERAGE 95 LACTATION PERIODS		(7) SCRUB COWS, AVERAGE 32 LACTATION PERIODS	
	Daily milk yield	Monthly percentage decline	Daily milk yield	Monthly percentage decline	Daily milk yield	Monthly percentage decline	Daily milk yield	Monthly percentage decline	Daily milk yield	Monthly percentage decline	Daily milk yield	Monthly percentage decline	Daily milk yield	Monthly percentage decline
	lbs.		lbs.		lbs.		lbs.		lbs.		lbs.		lbs.	
1	33.3						46.3		30.0		39.6		20.4	
2	34.3	103.0	35.1		35.1		45.4	98.1	29.4	98.0	40.3	101.8	19.0	93.1
3	32.3	94.1	33.3	94.9	32.8	93.4	41.9	92.3	27.9	94.9	38.9	96.5	16.0	84.2
4	29.9	92.6	31.3	93.9	30.4	92.7	38.9	92.8	25.9	92.8	36.5	93.8	14.0	87.5
5	28.1	94.0	29.3	93.0	28.7	94.4	36.2	93.1	24.2	93.4	33.9	92.9	12.0	85.7
6	26.4	94.0	27.8	94.9	27.3	95.1	33.5	92.5	22.7	93.8	32.5	95.9	9.7	80.8
7	24.9	94.3	26.4	95.0	25.9	94.9	30.9	92.2	21.4	94.3	30.8	94.8	8.0	82.5
8	23.7	95.2	25.1	95.1	24.3	93.8	27.5	89.0	20.6	96.3	29.3	95.1	7.0	87.5
9	22.4	94.5	23.8	94.8	22.6	93.0	24.4	88.7	19.5	94.7	27.9	95.2	5.4	77.1
10	21.0	93.8	22.5	94.5	20.6	91.2	20.4	85.7	18.6	95.4	25.4	91.0	3.7	68.5
11	19.5	92.9	21.5	96.4	17.9	86.9			17.3	93.0	23.2	91.3		
12	17.9	91.8	20.6	95.8	15.6	87.2			17.3	100.0	20.1	86.6		

(1) The records were compiled from the Guernsey Advanced Registry without selection.

(2) Only farrow cows were included.

(3) Only cows bred the third and fourth months were included.

(4) Compiled by Prof. F. W. Woll from the records of the Wisconsin and California Dairy Cow Competitions, Hoard's Dairyman, February 9, 1923, p. 109.

(5) The records were compiled from Jersey cows tested in Missouri.

(6) The records were compiled from Holstein cows owned by the University of Missouri.

(7) The data for the scrub cows was taken from chart 2, Iowa Agr. Exp. Sta. Bulletin 188.

[1] A theoretical discussion is given in the Journal of General Physiology, v, no. 4, 441.

As will be seen from table 1, this constancy in the percentage decline of milk secretion of the date available holds true to a remarkable degree. The Guernsey cow produces about 94 per cent of the previous month's production throughout the entire period of decline in milk secretion. There is a slightly larger percentage decrease during the last two or three months which is undoubtedly due to advanced pregnancy as the group of farrow cows do not show this decline at all, while another group of cows bred the third and fourth months show a more rapid percentage decline during the last three months of lactation.

The data compiled by Woll (4) consist of ten months records with definite calving requirement. The decline during the last several months is undoubtedly also due to pregnancy. The data for the Jerseys and Holsteins also show a very close agreement with the expected decline. Data on a limited number of scrub cows show a more rapid but fairly constant monthly percentage decline. This would naturally be expected of cows with short lactations.

SUMMARY

Data was presented showing the time of maximum milk production of Holstein-Friesian cows. It was suggested that the frequency of milking and the amount of milk produced are the most important factors governing the time of maximum production.

The percentage decline of milk secretion with the advance of the period of lactation was shown to be fairly constant. A slightly greater percentage decrease during the last two or three months of lactation was shown to be due to advanced pregnancy.

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SWEETENED CONDENSED MILK

I. BACTERIAL THICKENING

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For some years there have come to the attention of the writers samples of sweetened condensed milk which had been refused by the trade on account of having become extremely thick. In many cases the product is solid, in others it will barely flow when the cans are inverted, though sometimes it is merely clotted. Generally, there is a characteristic odor, not entirely unpleasant but which might be described as fruity; the taste is disagreeable. The acidity of the product is considerably above normal. No alteration in the color can be noticed and there is no evolution of gas. If the thickened product be vigorously stirred it becomes somewhat thinner but almost immediately sets to a glue-like mass.

When a portion of this milk is diluted with water and heated, a separation of curd takes place. By this test the kind of thickened milk which is here being described can be readily distinguished from thickening in condensed milk which results from physical causes such as has been studied by Rogers, Deysher and Evans (1). Age, or storage at high temperature, or exposure to high heat cause thickening but aside from high viscosity there is no other similarity between such a product and that which becomes thick due to bacterial action. There is no increase in acidity and no unusual odor connected with heat or age thickened milk.

Bacterial counts on these thickened samples are very high, often more than a million per gram. The organisms are almost entirely of the cocci form. Inoculation of cultures of these into condensed milk with relatively low total solids content is found to produce in a week or two conditions similar to those found in the commercial samples.

Bacterial thickened milk has been found to occur most commonly in late spring and summer and also in shipments to tropical climates.

GENERAL BACTERIOLOGY OF CONDENSED MILK

Perhaps the first to make a study of the deterioration of condensed milk from the point of view of the bacteriologist was Cassedebat (2). He concluded from his observations, that changes in the product were not due to bacteria, since he failed to find any organisms either living or dead. Nothing but molds, he believed, would grow in it.

Beginning with Hope (3), however, more careful studies have been made of the bacteriology of sweetened condensed milk, and all investigators have reported finding it non-sterile. (See references 4 to 17.) Previous investigations have, in general established the following points: (*a*) In good condensed milk the total number of bacteria is relatively low, usually but a few hundred per gram, and (*b*) when such a product is inoculated with a culture of bacteria the organisms not only do not grow, but the count often becomes less with time. (*c*) In samples of low grade condensed milk on the other hand, where some decomposition has taken place, the bacterial counts have been found to run into the millions (*d*) the coccus forms predominating in most cases. (*e*) Pathogenic bacteria are nearly always absent.

Aside from the true bacteria there too have been found in condensed milk organisms of the torula class and molds. Pethybridge (18), Hammer (19), Cassedebat (2), Rogers, Dahlberg and Evans (20) and others have described defects due to these organisms.

Previous investigations on bacterial thickening in condensed milk

Greig-Smith (21) reported finding commercial samples of condensed milk which had become coagulated and in which cocci were growing in large numbers. There is little doubt but that the condition he observed is identical with that which forms the subject of this work. It is probable that Dugardin's (22) experience with condensed milk of high acidity is related to this defect.

Hunziker (23) discusses "thickened and cheesy condensed milk" also and points out that the condition can be prevented by the use of unusually large amounts of sugar in the manufacture.

For the preservation of the sweetened condensed milk, therefore, chief dependence is placed upon the high sucrose concentration, except that torulae and molds are apparently able to grow in concentrations of sugar even up to the saturation point, and defects caused by these organisms can be prevented only by guarding against their entrance into the product during manufacture. But the true bacteria, at least those of common occurrence, can probably be checked if the concentration of sugar is high enough. Almost any table of results of analyses of condensed milk show the wide variations in sugar content not only between different brands but between different samples of the same brand, and this is particularly shown by a recent report from the Connecticut Agricultural Experiment Station (24). This may explain, therefore, why the investigators have in some samples found bacteria growing luxuriantly while in others, organisms would not multiply even when the product was heavily inoculated with them.

EXPERIMENTAL

It was the purpose in this work to look at the problem particularly from the manufacturer's point of view, to determine what standardization is necessary to prevent thickening, and to learn, if possible, why the defect occurs especially in condensed milk manufactured and stored during the summer and in that marketed in the tropics.

A study of the cultural characteristics, habitat and distribution of the organism causing thickening has not been completed and will be reserved for future report. However, sufficient has already been done along this line to show that it is, indeed, widely distributed. It has been isolated from practically all samples of sweetened condensed milk purchased on the market, fortunately being dormant in the majority of cases.

It seemed certain that these cocci must come from the factory in which the product is being made, since the species is not sufficiently heat resistant to withstand the operation of proc-

essing and could not reach the finished product from the raw milk entering the factory. In order to obtain what might be present in a milk plant which would grow in sweetened condensed milk an inoculum was obtained by mixing material taken from different places in a factory such as the packing of Jensen coolers, wall and floor scrapings, some slime from a cheese curing room and so on. A sample of normal condensed milk containing about 74 per cent total solids was reduced with water to 70, 65 and 60 per cent total solids. Into these portions a mixture of the above material was inoculated and incubated for about two weeks.

At the end of that time all samples were nearly solid and had the typical fruity odor which had already been experienced in the commercial samples. Upon examination it was found that coccus forms were present almost exclusively which when reinoculated into condensed milk a little low in total solids grew, accompanied by thickening of the product, development of the fruity odor and an increase in acidity. It would seem from this that condensed milk diluted down to 60 to 70 per cent total solids acts practically as a differential medium for these organisms.

Acidity produced in condensed milk by the organism

In normal fresh condensed milk the acidity calculated as lactic acid usually runs between 0.23 and 0.33 per cent. Commercial samples which show evidences of growth of the thickening organisms have been found to run as high as 0.75 per cent. Laboratory samples of low solids content inoculated with the organisms often reach more than 1 per cent. These facts suggest acidity titration as a means of estimating the relative growth of the organisms in different samples, and such determinations were accordingly made in all tests. The acidity in all experiments is calculated in terms of the percentage of lactic acid.

Growth of the thickening organism in condensed milk of different standardizations

Experiment 1. Three variables were taken into account in this experiment: percentages of sucrose, milk solids and water. In order to prepare samples for inoculation the following procedure

TABLE 1

SAMPLE	MILK SOLIDS	SUCROSE	WATER	SUGAR RATIO	ODOR	CONSISTENCY	ACIDITY	CONCLUSIONS AS TO GROWTH
	per cent	*per cent*	*per cent*					
1	26.0	46.6	27.4	63.0	OK	OK	0.238	0
2	24.5	47.5	28.0	62.9	OK	OK	0.247	0
3	27.1	45.8	27.1	62.8	OK	OK	0.256	0
4	29.6	44.2	26.2	62.8	OK	OK	0.305	0
5	32.5	42.4	25.1	62.8	OK	OK	0.279	0
6	31.0	43.3	25.7	62.7	OK	OK	0.360	?
7	24.1	46.9	29.0	61.8	OK	OK	0.232	0
8	24.1	46.9	29.0	61.8	OK	OK	0.232	0
9	25.6	45.9	28.5	61.7	OK	OK	0.267	0
10	25.6	45.9	28.5	61.7	OK	Heavy	0.337	+
11	26.7	45.2	28.1	61.6	OK	OK	0.283	0
12	26.7	45.2	28.1	61.6	OK	OK	0.275	0
13	29.2	43.6	27.2	61.5	OK	OK	0.284	0
14	29.2	43.6	27.2	61.5	Fruity	Heavy	0.338	+
15	30.6	42.7	26.7	61.5	Fruity	Solid	0.481	++
16	30.6	42.7	26.7	61.5	Fruity	Solid	0.558	++
17	32.1	41.8	26.1	61.5	OK	Heavy	0.373	+
18	32.1	41.8	26.1	61.5	OK	Solid	0.452	++
19	33.5	40.8	25.7	61.3	Fruity	Solid	0.252	+
20	23.7	46.3	30.0	60.6	OK	OK	0.311	+
21	25.3	45.2	29.5	60.5	OK	Heavy	0.311	+
22	26.4	44.5	29.1	60.4	OK	Heavy	0.365	+
23	28.7	43.0	28.3	60.3	OK	Solid	0.369	+
24	30.1	42.1	27.8	60.2	Fruity	Solid	0.463	++
25	31.6	41.2	27.2	60.2	Fruity	Solid	0.482	++
26	33.0	40.3	26.7	60.1	Fruity	Solid	0.387	++
27	33.0	40.3	26.7	60.1	Fruity	Solid	0.400	++
28	34.3	39.4	26.3	60.0	Fruity	Solid	0.360	++
29	23.4	45.6	31.0	59.5	Fruity	Heavy	0.292	+
30	24.9	44.6	30.5	59.4	Fruity	Heavy	0.352	+
31	26.0	43.9	30.1	59.3	Fruity	Solid	0.345	++
32	28.4	42.4	29.2	59.2	Fruity	Solid	0.459	++
33	29.7	41.5	28.8	59.0	OK	Heavy	0.302	+
34	31.2	40.6	28.2	59.0	Fruity	Solid	0.522	++
35	32.5	39.7	27.8	58.8	Fruity	Solid	0.512	++
36	33.8	38.8	27.4	58.6	Fruity	Solid	0.525	++
37	33.8	38.8	27.4	58.6	Fruity	Solid	0.572	++
38	35.7	36.9	27.4	57.4	Fruity	Solid	0.624	++
39	27.6	41.2	31.2	56.9	Fruity	Solid	0.594	++
40	35.2	36.4	28.4	56.2	Fruity	Solid	0.728	++
41	23.6	42.3	34.1	55.4	Fruity	Solid	0.550	++
42	36.5	34.3	29.2	54.0	Fruity	Solid	0.792	++
43	23.0	41.2	35.8	53.5	Fruity	Solid	0.644	++
44	37.5	32.6	29.9	52.2	Fruity	Solid	1.027	++

was followed: (*a*) About 18 pounds of sucrose was added to 100 pounds of whole milk; this was condensed down in a small vacuum pan to a high consistency. Upon analysis the batch was found to contain 43.0 per cent sucrose, 33.0 per cent milk solids and 24 per cent water. (*b*) Similarly a batch was prepared by adding sucrose at the rate of 2 pounds per 100 pounds of milk and condensing down. This was found to contain 10.0 per cent sucrose, 52.5 per cent milk solids and 37.5 per cent water. (*c*) A solution of sucrose in water was prepared containing 64 per cent sucrose. By mixing these three batches in various proportions a variety of standardizations could be obtained.

The various mixtures were inoculated with a liberal amount of a bouillon culture of the organism and the samples incubated at 30°C. for thirty-five days. At the end of this period the samples were inspected for consistency and odor and the acidity was determined, from which, conclusions were drawn concerning the growth of the organism. In table 1 are found the results. In the last column no growth is indicated by 0, slight growth, +, heavy growth ++.

From the percentages of sugar and of water in each sample there is calculated the percentage of sugar in solution in the water, disregarding for the moment other constituents, for instance, in sample 1, the percentage of sucrose is 46.6 which is 63.0 per cent of 74.0, the latter being the sum of the percentages of sucrose and water. For sake of convenience this will be called the "sugar ratio." In one column are found these ratios and the whole series is arranged in order of decreasing values.

Inspection of the table shows that at a sugar ratio of about 61.5 comes the dividing line, though it is not very sharp. At higher values growth seems not likely to take place while at all points below, growth is practically certain. At and near this line the milk solids is seen to vary considerably in the various samples, apparently without affecting the growth of the organism. It would seem, therefore, that the amount of sucrose in proportion to the water is the important factor in affecting the growth of thickening organisms.

No doubt this is correct generalization as far as practical application is concerned. However, from the milk solids a

considerable amount of lactose is in solution, and it is likely that the osmotic pressure due to the soluble lactose has an effect additive to that of the sucrose; both, then, would contribute toward inhibiting bacterial growth. But, in condensed milk the water is always saturated with respect to lactose, a large amount of insoluble phase being present, therefore, even though the milk solids varies in these experiments the percentage of lactose in solution in the water is always the same for a given temperature. As the other constituents of the milk cannot affect the osmotic pressure greatly, variation of milk solids in the standardization should not change the potency of the product to check bacterial growth.

Experiment 2. Condensed milk samples of different standardizations were prepared in this experiment in the same way that was described under experiment 1. The culture employed for inoculation was the same organism that was used in the previous experiment but it had been carried in the laboratory for about 4 months and was used without any particular effort to get it into an invigorated condition. The same proportions of culture were added as in the former experiment.

Results obtained here were of somewhat different order from those in the previous experiment. Although the time of incubation was three times that in experiment 1, much less activity was manifested by the organism, less acid was produced at all concentrations and very few of the samples had increased in viscosity more than a little. The line dividing the standardizations with respect to growth or no growth was found to be between the sugar ratios 59 and 60.

Again it was concluded that a variation in percentage of milk solids has no influence on the growth of the thickening organism. Consequently, in all later experiments only the relations of sucrose to water were taken into account, the milk solids being allowed to vary without control.

Experiment 3. A quantity of condensed milk was divided and diluted with water to successive standardizations. Each portion was further divided into two parts one being inoculated with a culture of the thickening organism invigorated by frequent

TABLE 2

SAMPLE	SUCROSE	WATER	SUGAR RATIO	CONSISTENCY AT END OF						ACIDITY AT END OF 31 DAYS	
				6 days		16 days		31 days			
				Invigorated	Non-invigorated	Invigorated	Non-invigorated	Invigorated	Non-invigorated	Invigorated	Non-invigorated
	per cent	*per cent*									
1	44.30	25.60	63.37	Normal	Normal	Normal	Normal	Normal	Normal	0.477	
2	44.16	25.94	63.00	Normal	Normal	Normal	Normal	Normal	Normal	0.567	0.423
3	43.95	26.09	62.75	Normal	Normal	Normal	Normal	Normal	Normal	0.639	
4	43.81	26.28	62.50	Normal	Normal	Normal	Normal	Normal	Normal	0.855	0.495
5	43.67	26.48	62.25	Normal	Normal	Heavy	Normal	Heavy	Normal	0.885	
6	43.53	26.68	62.00	Normal	Normal	Heavy	Normal	Heavy	Normal	0.900	0.630
7	43.39	26.87	61.75	Heavy	Normal	Solid	Normal	Solid	Normal	0.891	
8	43.24	27.06	61.50	Heavy	Normal	Solid	Normal	Solid	Normal	0.954	0.495
9	42.96	27.46	61.00	Heavy	Normal	Solid	Normal	Solid	Heavy	1.008	0.567
10	42.68	27.86	60.50	Heavy	Normal	Solid	Heavy	Solid	Heavy	1.053	0.684
11	42.40	28.26	60.00	Heavy	Normal	Solid	Solid	Solid	Solid	1.161	0.765
12	41.90	29.12	59.00	Solid	Heavy	Solid	Solid	Solid	Solid	1.269	0.837
13	41.40	29.98	58.00	Solid	Solid	Solid	Solid	Solid	Solid	1.287	0.801

transfers in bouillon and the other with an old culture which had been in the laboratory for some months without being transferred. All samples were incubated at 30°C. and inspections made at the end of six, sixteen and thirty-one days. In table 2 will be found the analysis of each sample together with the results of inspection.

The results obtained in this experiment as well as in experiments 1 and 2 give evidence that an invigorated culture of the organism grows in sweetened condensed milk much more rapidly and at a much higher sugar concentration than the same organisms in a less invigorated form. At the end of the incubation period the invigorated organism had thickened samples up to the sugar ratio 62.25 while in samples inoculated from the old culture thickening did not take place above 61.

These results also show that considerable bacterial activity had taken place in samples of sugar concentration above the point where thickening ceased. This was shown by the fact that considerable acid was produced (the acidity of the samples at the beginning was 0.42 per cent), and the fact that when quantities of these samples were heated with water a curd separated out.

Judging from acidity determinations and the hot water test all growth was checked in the samples inoculated with noninvigorated cultures at sugar ratios between 62.5 and 63 while the invigorated organism was active at all concentrations including the highest one in the experiment 63.25. It is evident, therefore, that the particular culture used here was more active than the one used in experiment 1 and in consequence the series of samples was not run to sufficiently high sugar ratios to find at what point the growth was absolutely inhibited. Accordingly another experiment was carried out starting with a batch of unusually high condensation.

Experiment 4. A special batch of sweetened milk was condensed to a high consistency and found to contain 46.4 per cent sucrose and 24.7 per cent moisture. As in the preceding experiment this was brought down by adding increasing quantities of water to successive portions. At each standardization the samples were inoculated with an invigorated culture. Every

effort was made to get the organism in the highest possible state of invigoration using as a medium skim milk containing 2 per cent sucrose. All samples were incubated at 30°C. for forty-three days, though by accident the temperature of the incubator was at about 20°C. for seven days of this time. In table 3 are given the chemical compositions of the batches together with the inspections made at the end of the incubation period. The coagulation test was applied by adding to a small quantity of the sample about four times as much water and heating to boiling.

TABLE 3

SAMPLE	SUCROSE	MOISTURE	SUGAR RATIO	CONSISTENCY	FRUITY ODOR	COAGULATION TEST	ACIDITY
	per cent	*per cent*					
Check	46.40	24.70	65.25	Normal	None	None	0.270
1	46.40	24.70	65.25	Normal	None	None	0.252
2	46.21	25.00	64.88	Normal	None	None	0.252
3	46.03	25.30	64.53	Normal	None	None	0.333
4	45.86	25.60	64.18	Heavy	Slight	Slight	0.333
5	45.66	25.89	63.81	Heavy	Slight	Slight	0.396
6	45.31	26.47	63.12	Heavy	Strong	Slight	0.513
7	45.13	26.76	62.77	Solid	Strong	Strong	0.612
8	44.96	27.04	62.44	Solid	Strong	Strong	0.513
9	44.78	27.32	62.10	Solid	Strong	Strong	0.630
10	44.44	27.85	61.47	Solid	Strong	Strong	0.693
11	44.27	28.16	61.12	Solid	Strong	Strong	0.621
12	43.77	28.96	60.18	Solid	Strong	Strong	0.684
13	43.44	29.50	59.55	Solid	Strong	Strong	0.675

It is concluded from these results that there is no sharp dividing line at which all growth of the organism ceases. The most objectionable evidence of growth, the solidification of the product, was stopped between the sugar ratios 62.77 and 63.12. Somewhat less thickening takes place from that point up to between 64.18 to 64.53, though judging from the acidity determinations there had been some growth of the organism even at the latter point. Further proof of this will be given under a discussion of the inversion of sucrose in these samples.

Bacterial counts were made on the samples from time to time throughout the experiment. The results were quite irregular. It was shown, however, while the numbers at first increased,

that before the conclusion of the experiment the counts in all samples had been rapidly becoming lower. There is no possibility, therefore, that different conclusions would have been drawn had the incubation period been longer.

Effect of temperature on the growth of the organisms

Under many conditions it was observed that cultures of the thickening organisms grew more vigorously at 30°C. or above, than at normal room temperatures, though data from only one experiment are available for presentation.

Experiment 5. Bouillon was prepared with quantities of sucrose varying from 5 per cent to 65 per cent. Inoculations were made with invigorated and noninvigorated cultures, and the samples were incubated at 20° and 30°. Observations were made as to acid production and bacterial growth at intervals from 24 hours to 80 days.

It was found that the noninvigorated bacteria would not grow and produce acid in sucrose above 40 per cent at 20° while at 30° they were active even in 55 per cent sucrose. Similarly, growth in the invigorated cultures was checked at 55 per cent sucrose at 20° while these organisms were active at 62 per cent sucrose at 30°. Observations showed also that the maximum activity was reached in all cases much sooner at 30° than at 20°.

These results prove that the optimum temperature for the growth of the organism is relatively high, also that the organisms can withstand and multiply in higher concentrations of sugar at the higher temperatures.

Destruction of sucrose and apparent increase in lactose caused by the activity of the thickening organism

On samples 1, 3 and 13 from experiment 3 (inoculations with invigorated cultures) sucrose and lactose determinations were made at the beginning and end of the incubation period. Sucrose was determined by applying the Clerget formula on polarizations obtained before and after inversion, and lactose by running the regular reduction procedure on the clear filtrates. The results were as follows:

SAMPLE	BEFORE INCUBATION		AFTER INCUBATION	
	Sucrose	Lactose	Sucrose	Lactose
1	44.30	12.35	36.43	16.86
3	43.95	12.25	38.81	15.13
13	41.40	11.63	36.15	19.05

Also the first 3 samples in experiment 4 were run for sucrose before and after incubation with the following results:

SAMPLE	SUCROSE BEFORE INCUBATION	SUCROSE AFTER INCUBATION
	per cent	*per cent*
1	46.40	46.41
2	46.21	46.20
3	46.03	45.40

From these results it is seen that the thickening organism attacks sucrose, part of it being inverted; since the formation of invert sugar, which is reflected in the apparent increase in lactose, is not sufficient to account for all the loss in sucrose (except in one case), no doubt some of the sucrose also is destroyed by the organisms.

DISCUSSION OF RESULTS

It has been found that in order to surely prevent growth of the organisms causing thickening in condensed milk under all conditions it is necessary that the sugar ratio be at least as high as 64.5. As the ratio falls below this figure the organism becomes more and more active until at about 63 a strong odor develops and actual solidification begins.

The government standard holds that sweetened condensed milk shall contain not less than 28 per cent milk solids. If for the sake of the safety the product is standardized at 28.5 per cent, this would leave 71.5 per cent for sucrose and water. In order to have a sugar ratio of 64.5 there should be, therefore, 64.5 per cent of 71.5 or 46.1 per cent sucrose with 25.4 per cent moisture. The total solids of this product would be 74.6 per cent. In condensed milk of this standardization no matter how highly invigorated the contaminating organism might be and no matter at what

temperature the product is held there should be no trace of growth of the thickening organism.

Calculation on the basis of a sugar ratio of 63.5, at which point there should be a reasonable safety from the dangers of actual solidification and the development of disagreeable flavors, gives the following figures: sucrose 45.4 per cent, moisture 26.1 per cent, total solids 73.9 per cent.

These standardizations are considered necessary when the contaminating organism is in its most active form and where the contaminated product is to be exposed to comparatively high temperatures. On the other hand the experiments recorded in this paper show that when these two sets of conditions are less favorable, somewhat lower sugar ratios would equally well prevent the development of the defects which result from the activity of the thickening organisms. This will account for the fact that though much of the milk on the market is standardized lower than is here found to be safe yet it does not all become defective, even though in most cases it does contain the organism.

One commercial sample of condensed milk was found which at ordinary room temperatures (in winter) did not undergo any change, but on being placed in the incubator it very soon developed typical thickening. On analysis this sample was found to run 43.80 per cent sucrose and 25.80 per cent moisture. The sugar ratio was, therefore, 62.93. In this product the organism must have been present in fairly active form and though the sugar ratio was below the safety point it was still high enough to prevent thickening as long as the sample was at ordinary room temperature, while at higher temperatures luxuriant growth of the organism was permitted.

Since these organisms could never withstand the heat to which the product is exposed in the operation of condensation, the contamination must take place in the factory after condensation is completed. The organisms growing thus in secluded points in the manufacturing equipment would be more likely to become invigorated in late spring and summer when the temperatures are higher; at the same time the finished product is exposed to higher temperatures at this time of the year which would be

particularly conducive to the activity of the organisms, though the latter condition would be equally fulfilled in shipments to torrid climates at any time of the year. These points are taken as explanations for the fact which the trade has observed that in the summer and in shipments to the tropics the phenomenon of thickening is most likely to take place.

It was found that under some conditions the thickening organism grows in condensed milk inverting some of the sucrose without altering the general appearance of the sample. For such a condition as this the control chemist should be on his guard. If some of the sucrose had been inverted then an analysis of the product does not show the quantity of sucrose originally added by the manufacturer. Unless special methods are followed the presence of invert sugar will throw the percentage of lactose too high. At the same time if the milk solids are determined either by subtracting percentage sucrose from total solids or by adding together the percentages of the various milk constituents then that figure will also be too high.

No doubt this will explain the abnormal results recorded by the Connecticut Experiment Station (24) where in some samples lactose was found extremely high and the sucrose correspondingly low.

Sweetened condensed skim milk

Though most of the work on the project of thickening has been done on condensed whole milk, a number of observations on condensed skim milk have shown that this product forms no exception to the theory just worked out.

With respect to milk solids the government standard for this product is the same as for whole milk—28 per cent. Assuming that sweetened condensed skim milk of this standardization is to be made there would remain 72 per cent for the sucrose and moisture. Taking a sugar ratio of 63.5, lower than which it is certainly not safe to go, there should be 45.72 per cent sucrose and 26.28 per cent moisture. Such a product would, therefore, contain 73.72 per cent total solids. It has been the experience of the writers and others, however, that such a product is ex-

tremely viscous when cold, so much so, in fact, that it could be handled only with great difficulty in the factory.

Two alternatives seems to have been followed by manufacturers; to make the product with 28 per cent milk solids and with sugar condense only to about 68 to 70 per cent total solids beyond which is not possible to go without the product becoming too thick to handle, or without regard for standardization adding sugar to the extent of about 18 per cent of the weight of skim milk and condensing down to the desired consistency.

Suppose in the first example there are 28 per cent milk solids, 42 per cent sugar and 30 per cent water. The sugar ratio would be 58.3. This figure is so far below the ratio necessary for preventing growth of the thickening organism that the product would be very likely to become decomposed through this agency. In fact, observation has shown that wherever such a product has been manufactured spoilage results in most cases.

If the manufacturer follows the other procedure, his product will contain usually about 24 per cent milk solids, 48 per cent sugar, and 28 per cent water. The sugar ratio would be, therefore, 63.15, a figure though not absolutely safe, yet with care in manufacturing and handling no great amount of spoilage would take place.

It is known that in many cases the manufacturer is following the latter method and thus ignoring the government standard. The results of the Connecticut Experiment Station show 3 out of 6 brands of skimmed condensed milk to be without doubt below the government standard; on account of the abnormal lactose values it is impossible to judge concerning the remainder.

SUMMARY

The organism causing thickening in condensed milk is a coccus, which is capable of inverting and destroying sucrose, and producing considerable quantities of acid.

It is able to grow in fairly high sucrose concentrations, though its growth is checked if the concentration is high enough. It is able to withstand a much higher concentration of sugar when

it is in an invigorated condition, also, at temperatures above normal room temperatures it is particularly active.

It has been isolated from factory equipment and probably it is at this point that the product is contaminated.

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A COMPARISON OF THE BABCOCK AND THE ROESE-GOTTLIEB (MOJONNIER) METHODS FOR DETERMINATION OF BUTTERFAT IN MILK

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The Babcock test for butterfat in milk has been used with but few changes since its discovery in 1890. During the period of over thirty years, however, several investigators have made comparisons as to its accuracy.

TABLE 1 (11)

Comparisons between the Babcock and gravimetric methods on whole milk

AUTHORITY	NUMBER OF COMPARISONS	AVERAGE OF ALL BABCOCK READINGS ABOVE AVERAGE OF ALL GRAVIMETRIC RESULTS	AVERAGE OF DIFFERENCES BETWEEN BABCOCK READINGS AND THE GRAVIMETRIC RESULTS*	ABSORBENT USED IN GRAVIMETRIC METHOD
Babcock (1)	30	0.011	±0.089	Asbestos
Snyder (2)	43	−0.026	±0.062	Asbestos
Farrington (3)	12§	0.050	±0.088	Asbestos
Farrington (3)	12§	−0.075	±0.093	Sand
Farrington (3)	12§	−0.129	±0.149	Paper
Connecticut Experiment Station (5)	32	within 0.01	6 differ over ±0.10	
Patterson (4)	20	−0.132	±0.153	Paper
Schutt (6)	32	−0.088†	±0.103§	
Heinrich (7)	27	−0.03‡		
Zehenter (8)	34	73.5 per cent within 0.05	3 differ over ±0.10	
Schrott-Fiechtl (9)	100	0.001	±0.076	Sand
Shiver (10)	49	0.067	±0.095	Paper

* Difference between comparisons on individual samples. This shows the average of the differences above or below the gravimetric method as contrasted with the previous column which shows the balance of these differences. The differences above and below the gravimetric method might be large and yet their balance be zero; thus showing too close an agreement between the two methods.

† From 12 of the comparisons.

‡ With 1500 revolutions, −0.22 with 800 revolutions. Diameter of wheel not given.

§ Same Babcock tests used.

A very complete summary of the work from 1890 to 1916 was prepared by Bailey (11).

A few other investigations had been made up to this time but the results were not altogether complete.

Julius Hortvet (12) in 1917 reported that the average of the results of ten different men showed that the Babcock test gave a reading of 0.04 per cent lower than the Roese-Gottlieb method.

Work carried out by Bailey (11) in 1916–1918 on 190 samples, showed fairly uniform results.

TABLE 2

Results of recent comparisons of the Babcock and Roese-Gottlieb methods for determination of fat in milk

AUTHORITY	YEAR REPORTED	NUMBER OF SAMPLES	METHODS USED	AVERAGE OF ALL BABCOCK READINGS ABOVE OTHER METHODS	PER CENT OF BABCOCK TESTS READING ABOVE ROESE-GOTTLIEB METHOD	VARIATIONS OF BABCOCK READINGS ABOVE ROESE-GOTTLIEB	AVERAGE OF ALL BABCOCK READINGS WITH GLYMOL BELOW OTHER METHODS
Bailey (11).....	1919	190	Grav.	0.000	92.1	−0.09 to +0.16	
Mojonnier and Troy (13).....	1922	14	Mojon.	0.022	64.3*	−0.15 to +0.16	
Mojonnier and Troy (13).....	1922	14	Adams	0.055	71.4	−0.11 to +0.21	
Hoyt (14).....	1922	28	Mojon.	0.116	100.0	+0.025 to +0.210	−0.025
Hoyt (14).....	1922	5	Mojon.	0.079	100.0	+0.025 to +0.115	−0.058
Hoyt (14).....	1922	5	Adams	0.091	80.0	−0.010 to +0.130	−0.046
Hoyt (14).....	1922	5	Asbestos	0.173	100.0	+0.110 to +0.220	+0.036
Dahlberg (15)...	1922	32	Mojon.	0.100	93.7*	−0.01 to +0.20	−0.09

* Reading on one sample same as Mojonnier.

Mojonnier and Troy (13) in 1922 reported some comparative work in which there was a rather wide variation in the results between the Babcock and Roese-Gottlieb (Mojonnier) methods.

Hoyt (14) and Dahlberg (15) presented reports to the California Creamery Operators Assn. at the Pacific Slope Dairy Products Show, Fresno, Calif., November 1922, showing that the average Babcock reading was considerably higher than the Roese-Gottlieb (Mojonnier) results. Since their results did not agree exactly, it was suggested that further work be undertaken.

OUTLINE OF WORK (BABCOCK METHOD)

The Babcock testing equipment, approved by the American Dairy Science Association (16) was used.

The 8 per cent milk test bottles were calibrated by the use of mercury, according to the standard of graduation which requires that 13.5471 grams of mercury shall fill the space equivalent to 5 per cent on the graduated column. Only bottles which were found to be completely accurate from the 0 to the 8 per cent mark and from the 2 to the 6 per cent mark were used. A small lens with a magnification of approximately × 3 was used to aid in obtaining the readings of the mercury.

All samples were obtained from a mixture of night and morning milkings, taken from the weigh can in the milk-receiving room of the University Farm Creamery. The samples were in perfect condition and were tested the same day as taken.

A one bottle torsion balance cream scale with a sensitivity of 10 milligrams was used and exactly 18 grams of milk, thoroughly mixed at a temperature of 60° to 70° F. was weighed into the test bottles.

Chemically pure sulphuric acid with a specific gravity of 1.82 to 1.83 was used at a temperature of 60° to 70°F.

A twenty inch Babcock Facile Steam turbine tester was used and the speed was held as closely as possible to 759 r.p.m. The tests were centrifuged, five, two, and one minutes, distilled water being added at a temperature of 190° to 200°F. They were then placed in a water bath for ten minutes at a temperature of 135° to 140°F. The readings were taken from the bottom of the lower meniscus to the extreme top of the upper meniscus by at least two members of the Dairy Industry Division. The readings were taken a second time, after the addition of glymol (colored mineral oil) to the tops of the fat columns. Average readings are recorded in table 3.

ROESE-GOTTLIEB (MOJONNIER) METHOD

The official Roese-Gottlieb analysis was obtained by using a Model-A Mojonnier tester. Approximately ten grams of milk was weighed directly into the fat extraction flasks. Only one

TABLE 3

Percentages of fat found in milk by the Babcock and the Mojonnier (Roese-Gottlieb) methods

SAMPLE	MOJONNIER			BABCOCK			BABCOCK (GLYMOL)		
	Original	Duplicate	Average	Original	Duplicate	Average	Original	Duplicate	Average
1	3.767	3.786	3.776	3.85	3.85	3.850	3.72	3.72	3.720
2	4.391	4.387	4.389	4.42	4.42	4.420	4.28	4.28	4.280
3	4.301	4.302	4.301	4.40	4.40	4.400	4.30	4.27	4.285
4	3.990	3.987	3.988	4.00	4.05	4.025	3.87	3.90	3.885
5	3.975	3.972	3.973	4.00	4.05	4.025	3.90	3.90	3.900
6	3.972	3.973	3.972	4.00	4.00	4.000	3.87	3.86	3.865
7	4.267	4.272	4.269	4.35	4.33	4.340	4.21	4.21	4.210
8	4.182	4.183	4.182	4.22	4.20	4.210	4.05	4.08	4.065
9	3.718	3.715	3.716	3.72	3.77	3.745	3.55	3.65	3.600
10	3.715	3.708	3.711	3.75	3.80	3.775	3.53	3.65	3.590
11	4.636	4.625	4.630	4.67	4.69	4.680	4.50	4.55	4.525
12	3.505	3.500	3.502	3.60	3.55	3.575	3.45	3.41	3.430
13	3.656	3.651	3.653	3.70	3.70	3.700	3.56	3.56	3.560
14	3.875	3.872	3.873	3.91	3.90	3.905	3.79	3.80	3.795
15	4.281	4.264	4.272	4.35	4.32	4.335	4.20	4.20	4.200
16	3.701	3.709	3.705	3.80	3.80	3.800	3.65	3.67	3.660
17	3.680	3.692	3.686	3.74	3.73	3.735	3.60	3.64	3.620
18	3.411	3.394	3.402	3.51	3.51	3.510	3.35	3.39	3.370
19	3.322	3.337	3.329	3.35	3.40	3.375	3.20	3.25	3.225
20	3.555	3.553	3.554	3.65	3.60	3.625	3.50	3.50	3.500
21	4.522	4.535	4.528	4.60	4.61	4.605	4.44	4.48	4.460
22	4.454	4.455	4.454	4.51	4.50	4.505	4.40	4.38	4.390
23	3.499	3.493	3.496	3.60	3.57	3.585	3.41	3.41	3.410
24	3.608	3.610	3.609	3.72	3.72	3.720	3.54	3.58	3.560
25	3.802	3.805	3.803	3.78	3.85	3.815	3.62	3.71	3.665
26	3.559	3.569	3.564	3.60	3.61	3.605	3.51	3.49	3.500
27	3.297	3.292	3.294	3.40	3.39	3.395	3.25	3.24	3.245
28	3.442	3.439	3.440	3.51	3.45	3.480	3.37	3.32	3.345
29	3.552	3.548	3.550	3.64	3.63	3.635	3.49	3.46	3.475
30	3.574	3.576	3.575	3.63	3.65	3.640	3.50	3.50	3.500
31	3.786	3.781	3.783	3.81	3.83	3.820	3.63	3.65	3.640
32	3.623	3.621	3.622	3.70	3.70	3.700	3.55	3.55	3.550
33	3.404	3.406	3.405	3.45	3.45	3.450	3.30	3.30	3.300
34	4.218	4.211	4.214	4.25	4.22	4.235	4.05	4.05	4.050
35	3.515	3.509	3.512	3.59	3.60	3.595	3.43	3.42	3.425
36	4.056	4.053	4.054	4.12	4.12	4.120	3.95	3.95	3.950
37	4.347	4.346	4.346	4.35	4.38	4.365	4.22	4.24	4.230
38	3.859	3.868	3.863	3.90	3.90	3.900	3.73	3.73	3.730
39	4.020	4.021	4.020	4.05	4.10	4.075	3.90	3.96	3.930
40	3.351	3.341	3.346	3.40	3.41	3.405	3.25	3.27	3.260

TABLE 3—*Continued*

SAMPLE	MOJONNIER			BABCOCK			BABCOCK (GLYMOL)		
	Original	Duplicate	Average	Original	Duplicate	Average	Original	Duplicate	Average
41	4.230	4.220	4.225	4.21	4.25	4.230	4.05	4.08	4.065
42	3.864	3.861	3.862	3.93	3.94	3.935	3.78	3.78	3.780
43	4.215	4.217	4.216	4.30	4.30	4.300	4.15	4.16	4.155
44	3.232	3.228	3.230	3.25	3.27	3.260	3.11	3.11	3.110
45	3.368	3.360	3.364	3.48	3.50	3.490	3.32	3.33	3.325
46	3.602	3.600	3.601	3.68	3.64	3.660	3.51	3.51	3.510
47	4.059	4.061	4.060	4.15	4.13	4.140	4.00	3.98	3.990
48	4.085	4.078	4.081	4.15	4.11	4.130	4.00	4.00	4.000
49	3.307	3.279	3.293	3.35	3.34	3.345	3.20	3.19	3.195
50	3.826	3.813	3.819	3.89	3.88	3.885	3.72	3.74	3.730
Averages.....			3.8222			3.8811			3.735

TABLE 4

Variations of percentages of fat in comparison of the Babcock and Roese-Gottlieb (Mojonnier) methods

SAMPLE	READING TO EXTREME TOP OF UPPER MENISCUS	READING WITH GLYMOL	SAMPLE	READING TO EXTREME TOP OF UPPER MENISCUS	READING WITH GLYMOL
1	+0.074	−0.056	27	+0.101	−0.049
2	+0.031	−0.109	28	+0.040	−0.095
3	+0.099	−0.016	29	+0.085	−0.075
4	+0.037	−0.103	30	+0.065	−0.075
5	+0.052	−0.073	31	+0.037	−0.143
6	+0.028	−0.107	32	+0.078	−0.072
7	+0.071	−0.059	33	+0.045	−0.105
8	+0.028	−0.117	34	+0.021	−0.164
9	+0.029	−0.116	35	+0.083	−0.087
10	+0.064	−0.121	36	+0.066	−0.104
11	+0.050	−0.105	37	+0.019	−0.116
12	+0.073	−0.072	38	+0.037	−0.133
13	+0.047	−0.093	39	+0.055	−0.090
14	+0.032	−0.078	40	+0.059	−0.086
15	+0.063	−0.072	41	+0.005	−0.160
16	+0.095	−0.045	42	+0.073	−0.082
17	+0.049	−0.066	43	+0.084	−0.061
18	+0.108	−0.032	44	+0.030	−0.0120
19	+0.046	−0.104	45	+0.126	−0.039
20	+0.071	−0.054	46	+0.059	−0.091
21	+0.077	−0.068	47	+0.080	−0.070
22	+0.051	−0.064	48	+0.049	−0.081
23	+0.089	−0.086	49	+0.052	−0.098
24	+0.111	−0.049	50	+0.066	−0.089
25	+0.012	−0.138			
26	+0.041	−0.064	Average....	+0.0588	−0.0870

sample was weighed at a time as it was thought that a slight error might be introduced if several pipettfuls were weighed at once. The reagents (distilled water, ammonia, alcohol, ethyl ether, petroleum ether) were of the best quality, as specified by Mojonnier and Troy (13). The Roese-Gottlieb process of fat extraction as described in the Mojonnier method (13) was used.

During the preliminary work, a comparison of the results from two extractions and three extractions was made, the third extraction making a slight increase of the third decimal point in the per cent of fat. It was also found that the addition of two drops of phenolphthalein indicator gave a similar increase. Consequently, the third extraction was omitted and the indicator added, since our object was to have the results represent as near the correct amount of butterfat as it was possible to obtain.

CONCLUSIONS

1. The Babcock test when read from the bottom of the lower meniscus to the extreme top of the upper meniscus, gave results which were higher than those obtained by the Roese-Gottlieb (Mojonnier) method. The average of 50 comparisons was found to be 0.0588 per cent.

2. The Babcock test gave readings which were higher in every case, the minimum variation from the Roese-Gottlieb (Mojonnier) being 0.005 per cent and the maximum 0.126 per cent.

3. When glymol (colored mineral oil) was added to the tops of the fat columns, an average reading was obtained which was 0.087 per cent lower than the average reading by the Mojonnier method.

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THE RELATIONSHIPS OF CONCENTRATION AND TIME TO THE TEMPERATURE OF COAGULATION OF EVAPORATED SKIM AND WHOLE MILK

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It is a well-recognized fact that the temperature of coagulation of an evaporated milk is dependent upon many factors. Among the factors that have been considered as influencing the temperature of coagulation are time of heating, acidity, H-ion concentration, homogenization, concentration of solids, time and temperature of forewarming, and shaking. Other factors sometimes mentioned are composition of the milk, stability of the proteins, and extraneous water present. These two latter are but secondary terms dependent upon other factors already mentioned. Some of these factors have been subjected to intensive study.

Sommers and Hart (1919) concluded that there is no consistent relation between the heat-coagulation temperature of milk and the titrable acidity, or between the heat coagulation and the H-ion concentration.

Rogers, Deysher and Evans (1921) found that the variation in the coagulation temperature of fresh mixed-herd milk is comparatively small and has little relation to the coagulation temperature of the same milk after evaporation. They also found that there is no definite relation between the coagulation temperature of evaporated milk and the H-ion concentration of the milk before sterilization. A very small increase in the acidity above the normal for a particular milk, however, will cause a distinct lowering of the coagulating temperature.

The latter found that forewarming temperatures much below 95°C. had little effect in raising the coagulating temperature; they also noted that forewarming for more than ten minutes

(within certain limits) at 95°C. changed the stability of the milk but slightly.

Work by Sommers and Hart (1919) and also by Milroy (1915) upon the mineral constituents of milk seems to show that heat treatment results in the precipitation of calcium, the presence of which renders the milk unstable toward heat.

Many of the other factors mentioned have not been studied systematically. In order to determine to what extent reliance can be placed on results obtained upon herd milk handled in various ways, and held for varying lengths of time, we have undertaken a study of some of the factors already mentioned.

EXPERIMENTAL

The milk used in all cases was a composite sample of herd milk received daily from the Government Dairy Farm 1, Beltsville, Md. Previous to evaporation each sample was forewarmed by bringing it to 95°C. upon a steam bath and maintaining it there with constant stirring for ten minutes. The samples were then transferred into large balloon flasks and the evaporation was carried out under a vacuum of approximately 28 inches. The temperature at which concentration took place was probably never more than 45° or 50°C.

After evaporation the resulting product was standardized to the concentration desired, sealed in baby size cans, and sterilized in a pilot sterilizer at various temperatures and for various lengths of time, according to the plans of the experiment. In order to make the results as nearly comparable as possible it was necessary to choose an arbitrary rate of time in which to raise the temperature of the sterilizer to the temperature at which the sterilization was to be made. All sterilizations were therefore brought to 100°C. in ten minutes and the additional temperature was added within a period of five minutes. This procedure is not wholly accurate, since in some cases where high temperatures were used the milks were subjected to a greater total heat treatment before the sterilization was actually begun than in those cases where lower temperatures were used. It approximates factory conditions, however, and brings the

product up to sterilization temperatures even when higher temperatures are used, thereby insuring greater accuracy in the time factor.

In several experiments upon an evaporated milk in the case of which the lengths of time chosen to bring the milk from 100°C. to the sterilization temperature were varied, it was found that the results were not markedly different. This would tend to show that the method is accurate unless the temperature of sterilization is exceedingly high.

SKIM VERSUS WHOLE MILK

It has been observed in the early part of our work that it was difficult to obtain checks upon various samples of milk received from day to day. The variations in coagulation temperature were too great to be accounted for by variations in the grade of milk. It was soon discovered that the different samples of milk did not contain exactly the same fat content, and inasmuch as the percentage of solids was calculated upon the total weight, any variation in the fat content would mean a variation in the percentage of water present after evaporation and consequently, perhaps, a great variation in the temperature of coagulation.

Although such an experiment would have no great bearing upon the commercial processes, it was decided to ascertain to what extent the presence of fats influences the coagulating temperature of an evaporated milk.

Three samples of whole evaporated milk were prepared from a composite sample of herd milk with a fat content of 3.8 per cent. Another portion of this milk was partially skimmed (final fat content 1.2 per cent), and three samples of whole milk partially skimmed were evaporated to concentrations of 16.5, 18 and 19.5 per cent solids not fat. In each case the fat and total-solid contents were determined, and the percentage of solids not fat was calculated upon *the total weight of the whole milk minus the total weight of the fat.*

Figure 1 shows the results obtained on these two samples of milk.

This experiment tends to show that a slight variation in the percentage of fat present has little effect upon the coagulation temperature of milk.

It seemed, however, throughout our work that there was a slight difference between the temperature of coagulation of the evaporated whole milk and that of the evaporated skim milk, the former always ranging a trifle higher. This could be determined only by a series of tests at various concentrations. Such a series of determinations was made with milk received upon three consecutive days.

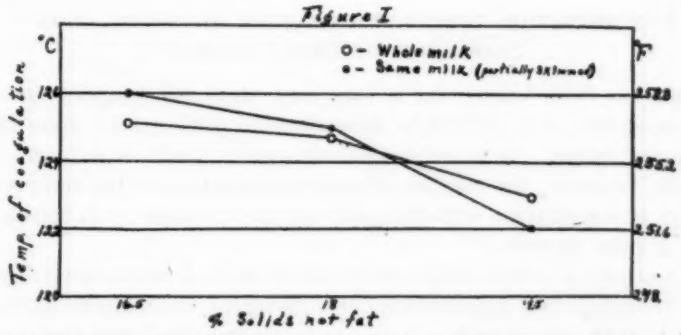

FIG. 1. EFFECT OF PARTIAL REMOVAL OF THE FAT IN MILK BEFORE EVAPORATION ON THE COAGULATION TEMPERATURE OF EVAPORATED MILK

For the results of this experiment, the reader is referred to figure 2, which also embodies the results for whole milk received on five consecutive days. These results seem to show clearly that the coagulation temperature of evaporated whole milk is a trifle higher than the coagulation temperature for evaporated skim milk, within the range of concentrations tried. Between the ranges of 16 and 20 per cent solids not fat, however, these differences are not great, the variations ranging from 1° to 1.5°C. for each percentage variation in concentration of solids not fat.

This difference in coagulating temperatures of whole and skim milks from the same sample is due, perhaps, to the absorption of heat by the fat present in whole milk. It has been found by Mr. Leighton, working in these laboratories, that with milks

of high fat content there is considerably more heat absorption than with skim milks when both are subjected to the same temperatures in an oil bath.

In all cases, however, where the percentage of fat in two milks did not vary too greatly, the results were approximately the same for the evaporated milks containing the same percentage of solids not fat, within the concentrations recorded.

The percentage of fat is deducted in all cases and all calculations are made upon the *total weight minus the weight of the fat.*

CONCENTRATION VERSUS TEMPERATURE OF COAGULATION—UNIFORMITY OF GRADE OF MILK

It has been known for a long time that the temperature of coagulation of a protein is dependent to some extent upon the concentration. In a heterogeneous system such as is found in milk, however, the relation of the concentration to the temperature of coagulation will obviously not be the same as in the case of a pure protein.

Samples of whole milk were received upon 5 consecutive days, evaporated, and standardized to 6 different concentrations, not more than one sample of any one concentration being prepared on the same day.

This not only gives the relation between concentration and coagulation temperature, but gives also an indication of the reliability of our method of sterilization and an indication of the uniformity of the samples of herd milk from day to day.

Figure 2 shows the temperature of coagulation, for thirty minutes sterilization, of the various concentrations used.

This figure seems to indicate that the relationship of the change of coagulation temperature to concentration is not a constant, within the limits of concentration used. At higher concentrations there is a greater variation in the temperature of coagulation for every change of concentration than there is at the lower concentrations. The difference in temperature of coagulation for every 1 per cent difference in concentration when the percentage of solids not fat is between 16 and 26 per cent, in our method, seems to be about 1.25° to 1.50°C.

The variation in the temperature of coagulation of a certain concentration from day to day is not great in the milk received at this laboratory, as shown by points in the figure. At the higher concentrations the concordance of results is very good. At the lower concentrations results do not check so well. This can be accounted for when we consider that at higher temperatures (lower concentrations), in the method of sterilization used, there is a greater chance for error in bringing the product up to the temperature at which sterilization is to take place.

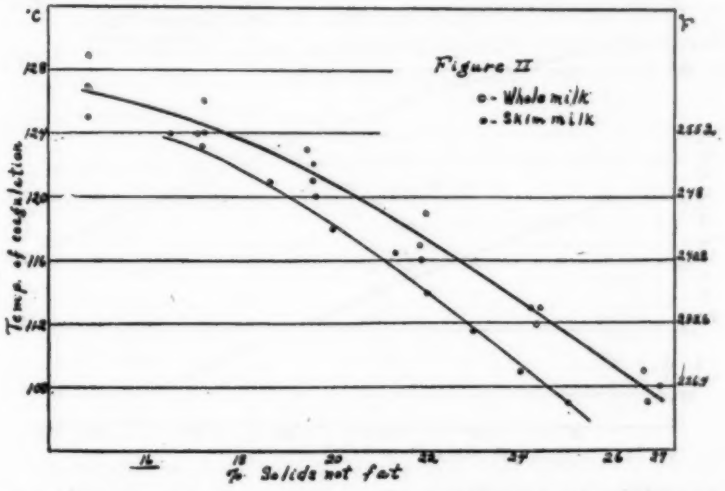

FIG. 2. RELATIONSHIP OF TEMPERATURE OF COAGULATION TO VARIOUS CONCENTRATIONS OF EVAPORATED SKIM MILK AND EVAPORATED WHOLE MILK

Figure 2 indicates that the change of coagulation temperature for changes of concentration of evaporated skim and whole milks is somewhat greater for evaporated skim milk than for evaporated whole milk.

The variation in the quality of the herd milk used from day to day as regards coagulation temperature is small. Any change in the percentage of solids not fat, not exceeding 0.3 per cent, causes a change in the coagulating temperature which is entirely within the range of error in sterilization.

Whether or not milk of inferior grade will have the same relationship of concentration and temperature of coagulation as fresh milk of good quality was ascertained by determination of the relation of the time to the coagulation temperatures of a milk that had been held at about 18°C. for twenty-four hours. This milk showed a decided drop in the temperature of coagulation.

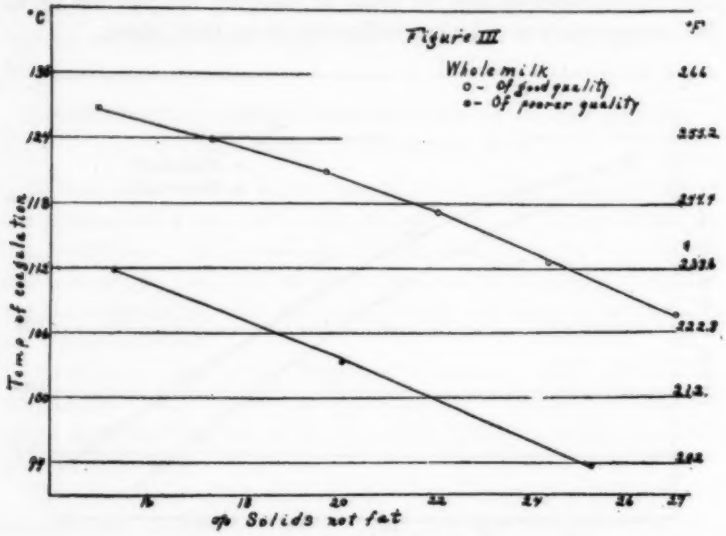

FIG. 3. RELATIONSHIP OF TIME AND TEMPERATURE OF COAGULATION IN MILK OF INFERIOR GRADE AND A MILK OF GOOD QUALITY

Figure 3 shows the relationship of time and temperature of coagulation of such a milk.

In the case of milk of inferior quality there is a decidedly lower coagulating temperature, but the relationship of concentration and temperature seems to be the same as for the milk of good quality.

The change in the inferior milk was undoubtedly caused largely by acid-forming bacteria. Whether or not this relationship will hold for any other type of flora is an open question. Some of

the results obtained at this laboratory seem to show that there may be variations in the type of change caused by various flora.

TIME-TEMPERATURE RELATIONS IN STERILIZATIONS

No definite time and temperature of sterilization can be specified as giving the best results. These two factors must be adjusted to the quality of the milk on hand.

While it was the purpose of this experiment to find the relationship that exists between the time of sterilization and the temperature of coagulation, the authors have realized that the milk under examination is superior in quality to the milks received at most factories, and therefore have tried to ascertain whether the relations that hold for good milk will also hold for milk of inferior grade.

TABLE 1

Temperatures of coagulation of evaporated milk (18 per cent solids-not-fat) for various time periods

TIME	TEMPERATURE OF COAGULATION	
minutes	°C.	°F.
10	131	267.8
12	128	262.4
20	123	253.4
30	119	246.2
45	116	240.8
60	114.5	238.0

A sample of milk containing 18 per cent solids not fat was prepared and the temperatures of coagulation were determined for the various time periods.

Table 1 gives the results obtained with a fresh sample of evaporated milk.

Inasmuch as the temperatures usually employed for sterilization in factories are considerably lower than those used in this experiment, it might be possible that the relationships shown in the table above will not hold for milks of poorer grade. In order to determine this a fresh sample was kept at a low temperature until it showed a decided drop in its coagulation temperature.

A sample of evaporated milk was prepared containing 18 per cent solids not fat, and the temperatures of coagulation for the various periods of time were determined as in the former experiment. The results are seen in table 2.

TABLE 2

Temperatures of coagulation of a sample of milk which had been held for seven days at a temperature of 7° to 10°C.

TIME	TEMPERATURE OF COAGULATION	
minutes	*°C.*	*°F.*
15	116	240.8
30	110	230
45	107	224.6

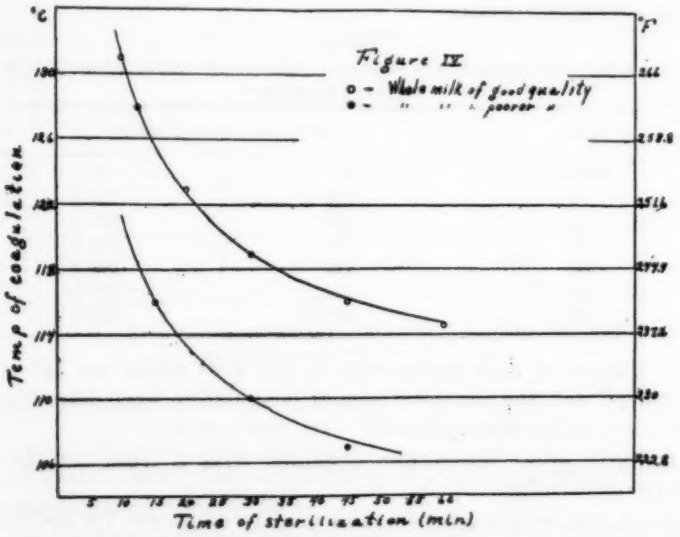

FIG. 4. RELATION BETWEEN TIMES AND TEMPERATURE OF COAGULATION IN TWO GRADES OF MILK FROM THE SAME HERD, AFTER EVAPORATION

The relations are more clearly brought out in figure 4.

The data seem to indicate that there is no sharp break in the relationship of time to temperature.

The relation of the variations in temperature of sterilization to those in time of sterilization approaches very closely a logarithmic nature. How closely this relation holds for the experiments recorded is shown in figure 5, where the logarithm of the total change in temperature from the temperature of coagulation at sixty minutes is plotted against the time in minutes.

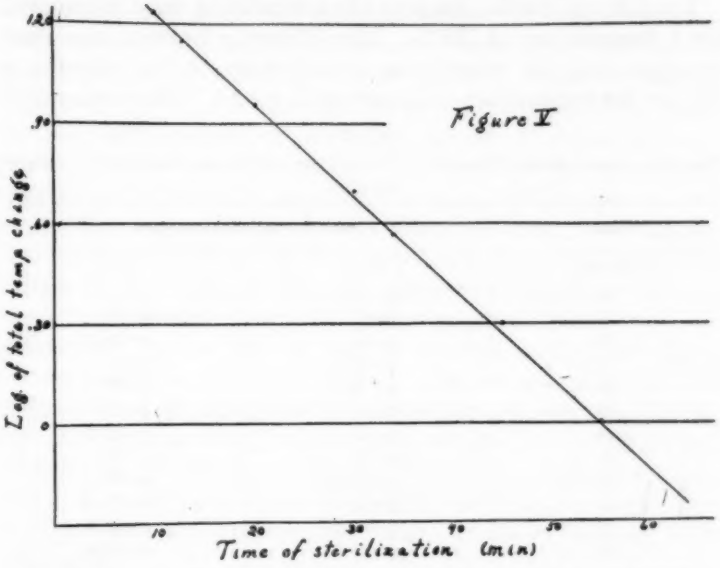

FIG. 5. SHOWING THE LOGARITHMIC NATURE OF THE RELATIONS SHOWN IN FIGURE 4

The data presented show that if the coagulating temperature of an evaporated milk, of approximately 18 per cent solids not fat, for a certain time period is known, we can predict approximately the temperature of coagulation for any other period of time; or vice versa, the time period required for any other temperature. For convenience a table such as the one given below might be of value, and it is perhaps better suited to practical use than a formula would be. Table 3 indicates the degrees that must be subtracted from the coagulating temperature (y) of

any evaporated milk containing approximately 18 per cent solids not fat, for a ten-minute period, at each successive five-minute period.

If the coagulation temperature of an evaporated milk for a ten-minute period is found to be 130°C., the coagulation temperature for a thirty-minute period will be $y-12$ or 118°C.

For this same milk, suppose the coagulating time is required for a temperature of 120°C. The difference between this temperature and the coagulating temperature at ten minutes is 10°; or the coagulation temperature is $y-10$. The correspond-

TABLE 3

Variation in coagulating temperature for each time period in a series at five-minute intervals

TIME	TEMPERATURE OF COAGULATION	
minutes	°C.	°F.
10	y	y
15	$y-5$	$y-9$
20	$y-8$	$y-14.4$
25	$y-10.5$	$y-19$
30	$y-12$	$y-21.6$
35	$y-13$	$y-23.4$
40	$y-14$	$y-25.2$
45	$y-15$	$y-27$
50	$y-15.5$	$y-28$
55	$y-16$	$y-28.8$
60	$y-16.5$	$y-29.7$
75	$y-17$	$y-30.6$

ing time will be twenty-four minutes. Again, if a milk just coagulates at 119°C. in thirty minutes, the temperature of coagulation for a forty-five minute period will be $(y-15)-(y-12)$ or 3°C. less than the coagulating temperature for thirty minutes, or 116°C.

Knowing that this milk coagulates at 119°C. in thirty minutes, one can ascertain the time required for a temperature of 123°C. as follows. The coagulation temperature for thirty minutes is 119°C., or is represented by $y-12$. The temperature 123°C. is 4° greater then the temperature for which the time is known, and will be represented by $y-8$. The time corresponding to $y-8$ as coagulating temperature, is twenty minutes.

In order to avoid confusion in calculations it is well to keep always in mind that the higher the temperature the shorter the time, and vice versa.

SUMMARY

In order to make the results obtained upon various milks comparable with respect to time and temperature of coagulation it is necessary to calculate all concentrations upon the basis of the proportion of solids not fat to the total weight minus the weight of the fat. While calculations of solids upon the basis of total solids (including fat) will hold for all milks with approximately the same fat content, any variations in the percentage of fat will introduce error into the data of true concentration of proteins and consequently will introduce error into coagulation data. A calculation of results upon the basis suggested will give a true basis for the comparison of the stability of evaporated milks toward heat, and make possible a comparison of milks from day to day, as well as of skim and whole milks, whatever may be their fat content. The presence of a high fat content in a milk will raise its coagulating temperature slightly over that of skim milk from the same sample, due in all probability to the absorption of heat by the fat present in the whole milk. It would seem therefore that in studying the mechanism of coagulation the most reliable results would be obtained with skim milk.

The relation of the coagulation temperature to the concentration of evaporated milk, between the concentrations of 16 and 26 per cent, has been determined. The greater the concentration the greater the variation between skim and whole evaporated milk from the same sample.

In the region of concentration which is of most interest (18 to 20 per cent) the change of coagulation temperature for every 1 per cent change in concentration is approximately 1.5°C. In higher concentrations the change is slightly more.

The relation between concentration and coagulation temperature in a milk of poor quality seems to parallel that in a milk of good quality.

The relation of the temperature of coagulation to the time of coagulation has been determined between ten and sixty minutes and found to approximate very closely a logarithmic relation, with respect to time. Knowing the time and temperature of coagulation of a milk of certain concentration, therefore, one can approximate the temperature of coagulation for any other period of time. The same relationship between time and temperature seems to hold for milks of poorer grade.

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THE VALUE OF MILK INSPECTION FOR A SMALL CITY

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The value of milk inspection for a small city is very conclusively shown in the results of a series of surveys conducted in the city of LaFayette, Indiana, over a period of nearly two years.

In October 1921, a survey was made to determine the quality of the milk sold. It was found that there were 37 distributors of which 34 were also producers, and all but 2 were selling milk in the raw state. During the month at different intervals six samples of milk were collected from each distributor and the bacterial count determined according to Standard Methods of Milk Analysis 1921, the per cent of milk fat, visible dirt and total solids. The per cent milk fat in all cases was well above the State standard of 3.25 per cent and judging from the total solids no water adulteration was found. Sixty-six per cent of the samples collected contained more than 1,000,000 organisms per cubic centimeter the highest count obtained being 7,000,000 and the lowest 270,000 organisms per cubic centimeter. The bacterial count had little or no time to increase for the samples were taken from the wagons as they made their early morning delivery and in all cases immediately placed on ice and plated within two hours. The amount of visible dirt found on sediment discs showed only two distributors and one of those was using a clarifier had pads equal to a No. 1 pad, the remaining grading downward. Public sentiment was aroused thru a series of meetings and thru the local medical association, causing the city administration to act.

Early in 1922 a veterinarian was appointed milk inspector by the city administration, to devote one fourth his time in endeavoring to have the producers tuberculin test their cattle and to instruct them in better methods of handling milk. In a survey which was made the latter part of March following the same procedure as the previous survey, it was shown that 38 per

cent of the samples collected had more than a million organisms per cubic centimeter and 20 per cent with 50,000 or less, and 80 per cent of the sediment discs graded out no. 1. The highest count shown in March was 4,190,000 and the lowest 10,000. Owing to the pressure of his professional work no inspection or instructional work was carried on from March to June, and with warmer weather conditions the survey conducted in June shows an increase in bacterial content of the milk. Forty-two per cent of the samples collected had more than 1,000,000 and only 5 per cent with a count of less than 100,000.

In October, 1922, the milk inspector resigned and another veterinarian appointed under the same conditions. The following program was outlined:

1. That samples were to be collected at different intervals during the month from the majority of distributors, especially those who continued to give high counts.

2. Each distributor was to be informed personally as to the condition of his milk and methods to be used for bettering his milk.

3. That results be published in the local paper.

4. To have all the milk that is sold in a raw state from tuberculin tested cattle.

5. That a series of meetings to be held with the distributors to discuss means of bettering the milk supply. The survey made in November after one months work of the inspector showed 4 per cent of the samples collected to be over 1,000,000 and 72 per cent under 100,000. The inspector had particularly instructed them in the means of removing visible dirt and means of sterilizing their utensils. Similar surveys were conducted during the months of December to May, 1923, of which the results are explained in the following table. In the case of October, 1921, March and June, 1922, samples were obtained from all the distributors. In the succeeding surveys a majority of the distributors' milk was analyzed. The inspector endeavored to obtain samples from those distributors whose milk was of the poorest quality in previous surveys.

TABLE 1

The percentage distribution of samples collected from distributors in regards to bacterial content

COUNT	OCTOBER, 1921	MARCH, 1922	JUNE, 1922	NOVEMBER, 1922	DECEMBER, 1922	JANUARY, 1923	FEBRUARY, 1923	MARCH, 1923	APRIL, 1923	MAY, 1923
5,000–10,000		5		4		30.6	55	7	20	
11,000–25,000		5	5	28	17	12.6	7	14	30	8
26,000–50,000		10		24	10	12.6	23	14		30
51,000–100,000				16	10	19.0	15	28		8
101,000–250,000	9	32	5	16	50	6.3		7		8
251,000–500,000	9	5	27	8	13	6.3		14	20	16
501,000–1,000,000	16	5	21			6.3		14	30	30
1,001,000–over	66	38	42	4						

SUMMARY

That milk inspection service in small cities is practical and by expending a comparatively small amount of money, in the case of the city of LaFayette $1000 per year covered all expenses, a marked improvement upon the quality of milk can be obtained. The results quoted were accomplished by a veterinarian devoting one-fourth of his time. Devoting of more time by the inspector and the conduction of more surveys would undoubtedly yield greater improvement.

STUDIES IN THE GROWTH AND NUTRITION OF DAIRY CALVES

VIII. RAISING DAIRY HEIFERS BY MEANS OF THE SELF-FEEDER

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The self-feeder is now recognized as a valuable adjunct in the feeding of hogs and also to some extent in fattening beef cattle. Its use with dairy cattle is still in the experimental stage, however, and the project reported here is supplementary to the work outlined in paper VII of this series.

RÉSUMÉ OF PREVIOUS WORK

Part of the work on the use of self-feeders and problems intimately connected with their use has already been reviewed in paper VII of this series but a few additional references may be given here.

Among the few references obtainable it is found that both Cook (59) and Nevens (62) reported good results where a grain mixture was provided in a self-feeder for calves. On the other hand, Hunt (61) found that cows in milk, when allowed access to a self-feeder, consumed so much grain that milk production was very uneconomical.

A report has already been given of the preference of young calves for whole grains and Hanly (60) obtained similar results, while Woll and Voorhies (63) found a slight advantage in feeding ground grain but the difference was not sufficient to pay for the grinding.

EXPERIMENTAL WORK

The work outlined here was undertaken with the view of ascertaining the possibility of raising dairy heifer calves from birth to the age of first freshening with the aid of the self-feeder.

The feeds used were very similar to those used in the earlier work reported in paper VII of this series, with the exception that gluten feed and hominy meal, which had proved to be unpalatable, were excluded.

Three purebred heifer calves were used. All were in good growthy condition when put on the self-feeder at an average age of 27 days. Information concerning them is given in table 45 and where necessary it is calculated to October 5, 1919, the day on which the trial started.

TABLE 45

Animals used

	CALF 487	CALF 491	CALF 493	AVERAGE
Breed	Jersey	Ayrshire	Holstein	
Birth weight *pounds*	64	60	80	68
Age, *days*	43	20	19	27

TABLE 46

Previous feed

	CALF 487	CALF 491	CALF 493	TOTAL	AVERAGE
Sucking, *days*	1	6	5	12	4
Whole milk, *pounds*	359	103	103	565	188
Pasture, *hours*	328	104	104	536	179

From the time of removal from their dams, until the beginning of the experiment, the calves had been receiving whole milk and were on pasture a few hours daily. In addition, calf 487 had also had a little hay and grain before the start of the trial.

All feed records were kept by 30-day periods and at the end of each period the animals were weighed on each of three successive days and the average of the three weighings was considered to be the weight of the animals at the end of the period. The height at withers, depth of chest and width at hooks was also determined for each animal.

The original intention was to carry the animals to the age of first freshening but as difficulties apparently arose regarding the breeding of the heifers, the trial had to be discontinued at the end of the twenty-second period.

At the beginning of the experiment the animals were all receiving whole milk, hand fed, and had before them at all times alfalfa hay and salt. The self-feeder kept in their pen contained the following concentrates:

Shelled corn
Cracked corn
Whole oats
Ground oats
Wheat bran
Linseed oil meal O. P.

The calves were turned out daily for exercise and water and during the first 27 days they were on pasture for 8 hours daily. During the winter they were exercised and watered daily in the dry lot. When the pasture was ready in spring the heifers were turned out. The three animals were on a pasture of 2.09 acres and for shelter they had an open shed in which the self-feeder was kept.

The feeding of milk and alfalfa was discontinued during the eighth period and from the beginning of the ninth period to the end of the trial the animals were continuously on pasture but had access to the self-feeder at all times up to the end of period XVIII. Periods XV to XX were in winter and during that time alfalfa hay was again fed and silage was also allowed. In this winter period, however, the heifers also obtained some feed from the pasture. In the last two periods pasture alone was allowed.

DISCUSSION OF RESULTS

The feed records were kept by 30-day periods but in order to study the early actions of the calves the record for the first 30 days was kept in 10-day periods. In considering this first period it is found that the calves took readily to the whole corn and whole oats and consumed considerably less of the ground feeds. They consumed a relatively liberal amount of wheat bran but only about half as much oil meal as whole corn or whole oats. Their consumption of grain was greater during the first 10 days than was their consumption of alfalfa hay, but during the second 10-day period they decreased their grain consumption,

particularly the oil meal and bran and increased their hay consumption. Evidently therefore, they took relatively too much grain during the first 10 days but immediately proceeded to correct it as their hay consumption exceeded their grain consumption for the 30-day period.

TABLE 47

Feed consumption during period I

	SUB-PERIOD			TOTAL	AVERAGE PER HEIFER
	i	ii	iii		
	pounds	*pounds*	*pounds*	*pounds*	*pounds*
Whole milk	263	309	312	884	295
Whole corn	3.2	5.6	1.9	10.7	3.6
Cracked corn	0.0	0.9	0.9	1.8	0.6
Whole oats	2.4	2.8	5.6	10.8	3.6
Ground oats	1.2	0.5	3.2	4.9	1.6
Wheat bran	4.0	1.9	1.4	7.3	2.4
Oil meal	3.2	0.0	1.4	4.6	1.5
Alfalfa hay	4.8	15.8	27.3	47.9	16.0

TABLE 48

Individual milk consumption

PERIOD NUMBER	CALF 487		CALF 491		CALF 493		TOTAL		AVERAGE	
	Whole milk	Skim milk	Whole milk	Skim milk	Whole milk	Skim milk	Whole milk	Skim milk	Whole milk	Skim milk
	pounds	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*
I	294		262		328		884		295	
II	302		302		392		996		332	
III	315		212	138	256	161	783	299	261	100
IV	315		180	180	210	210	705	390	235	130
V	315		180	180	210	210	705	390	235	130
VI	296	15	162	192	189	225	647	432	216	144
VII	120	199		260		336	120	795	40	265
VIII		90				90		180		60
Total.....	1957	304	1298	950	1585	1232	4840	2486	1613	829

The milk feeding was at no time heavy, the animals being fed limited amounts twice daily, as it was felt best to allow the calves to choose their own feeds as much as possible. The fact that the calves did not lack for feed and developed well even on limited amounts of milk is shown by the live weight gains.

In considering the total amounts of feed consumed it is found that cracked corn came first among the concentrates and was followed closely by whole corn, while whole oats was considerably behind, amounting to only about one-third of the whole corn. The amount of oil meal consumed was only about half that of whole oats while wheat bran was considerably lower and the ground oats consumed was but a very small amount. Roughly, there was one and a half times as much whole corn consumed as of all other concentrates combined, with the exception of cracked corn which was consumed in even larger amounts than the whole corn.

The total consumption of the various grains is perhaps not of as great interest as the changes which take place in the relative amounts of them consumed at various stages in the trial. During the first six periods when the amounts of whole milk fed exceeded the skim milk there was a steady increase in the amount of whole corn consumed while the cracked was consumed in insignificant amounts. The same holds true for both whole and ground oats, in fact the calves appear to have tried them at first and then decreased their consumption of them. The wheat bran also formed an insignificant part of the grain ration during this time, though the amount of oil meal used increased considerably with the exception of a very severe drop in the fifth period.

In the seventh period the skim milk fed exceeded the whole milk and in the eighth period skim milk alone was used for a time. The consumption of the whole corn reached its peak in the seventh period, probably owing to its use for the replacements of the butterfat removed from the ration, but in the eighth period it dropped. This drop in whole corn consumption was accompanied by an enormous increase in the amount of whole oats used. The bran consumption increased greatly during the seventh and eighth periods and that of oil meal also went up, while the amounts of cracked corn and ground oats consumed remained low.

The heifers were turned to pasture at the beginning of the ninth period and from there to the end of the fourteenth period they were under summer conditions and receiving no milk. Through-

out this time the consumption of whole corn decreased and that of cracked corn increased. The consumption of oats in any form was low until the last 30-day period of this section when the amount of whole oats consumed was large. The consumption of bran was somewhat irregular though with a tendency to increase

TABLE 49

Total feed consumption by 30-day periods

PERIOD NUMBER	WHOLE MILK	SKIM MILK	WHOLE CORN	CRACKED CORN	WHOLE OATS	GROUND OATS	WHEAT BRAN	OIL MEAL	ALFALFA HAY	CORN SILAGE	SALT
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
I	884		11	2	11	5	7	5	48		0.31
II	996		24	6	44	15	1	2	133		0.23
III	783	299	208	2	0	25	0	27	122		0.24
IV	705	390	308	0	6	13	0	99	153		0.09
V	705	390	466	0	9	11	2	7	129		0.06
VI	647	433	577	5	1	6	2	96	144		0.19
VII	120	795	651	8	1	7	43	111	149		0.05
VIII		180	538	6	180	7	52	118	157		0.60
IX			490	327	16	0	4	0			1.44
X			511	438	26	19	77	46			1.05
XI			343	612	0	0	33	17			1.04
XII			508	329	23	9	79	51			1.03
XIII			448	685	51	24	15	80			1.04
XIV			252	732	188	0	73	59			1.05
XV			31	835	172	33	0	91	242	674	0.84
XVI			44	927	480	23	14	31	165	106	0.70
XVII			1	913	399	0	0	21	199	192	0.65
XVIII			412	584	235	0	16	13	254	219	0.72
XIX									537	892	0.83
XX									142	1425	1.20
XXI											1.16
XXII											1.01
Total.....	4840	2487	5823	6411	1842	197	418	874	2574	3508	15.58

when compared with the previous production. The oil meal consumption dropped to zero during the first thirty days on pasture and during summer was never high.

During the fifteenth to eighteenth periods corn silage and alfalfa hay were given at free will and during this time the whole

corn consumption decreased and that of cracked corn increased until the last 30 days when there was a radical change in the opposite direction. The consumption of whole oats increased with the exception of the last period. Ground oats and bran were consumed in but small amounts and the consumption of oil meal though increased in the first 30 days declined towards the end.

TABLE 50

Consumption of whole and ground grains

PERIOD NUMBER	WHOLE GRAIN			GROUND GRAIN			AMOUNT OF WHOLE GRAIN PER POUND OF GROUND GRAIN
	Corn	Oats	Total	Corn	Oats	Total	
	pounds	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*
I	11	11	22	2	5	7	3.1
II	24	44	68	6	15	21	3.2
III	208	0	208	2	25	27	9.6
IV	308	6	314	0	13	13	24.2
V	466	9	475	0	11	11	43.2
VI	577	1	578	5	6	11	52.5
VII	651	1	652	8	7	15	43.5
VIII	538	180	718	6	7	13	55.2
IX	490	16	506	327	0	327	1.5
X	511	26	537	438	19	457	1.2
XI	343	0	343	612	0	612	0.6
XII	508	23	531	329	9	338	1.2
XIII	448	51	499	685	24	709	0.7
XIV	252	188	440	732	0	732	0.6
XV	31	172	203	835	33	868	0.2
XVI	44	480	524	927	23	950	0.6
XVII	1	399	400	913	0	913	0.4
XVIII	412	235	647	584	0	584	1.1

From the time the calves were put on the trial until they went to pasture, 210 days later, they had free access to alfalfa hay and the consumption of this increased fairly readily. During the following summer they had no roughage but pasture but at the approach of winter they were given corn silage and alfalfa hay. These roughages were fed for 6 months and during the first 4, grain was also being given. During the first period of feeding the silage was consumed in fair amounts but for the next three little of it was consumed as it frequently froze before the heifers would

consume it. The consumption of hay remained fairly constant. For the two periods after the grain was removed the silage consumption increased greatly and there was an increase in hay consumption for 1 month but in the last month it was inhibited probably by the greater silage consumption and the freshening of the pasture. In the last two months of the trial the animals received pasture only.

The salt consumption increased irregularly from the start of the trial until the calves were weaned and put to pasture. At this stage there was a great increase in salt consumption and this was fairly well maintained until the introduction of alfalfa and silage at the beginning of winter when the salt consumption again fell and remained low until after the grain had been removed and the heifers were beginning to get fresh pasture again. At this time it again rose and remained so until the trial ended.

In comparing the amounts of whole corn and oats consumed with the amount of the ground grains utilized, it is found that from the beginning of the trial until the end of the eighth period, when the calves were weaned and put to pasture, that the amount of whole grain increased from 3.1 pounds per pound of ground grain consumed in the first period to 55.2 pounds per pound of ground grain in the eighth period. During this time therefore the preference of the calves was for whole grains. From then on however, whether the calves were on pasture or on alfalfa and corn silage, there was no such marked preference for the whole grains. Sometimes they consumed more whole than ground grains and at other times considerably less.

Taking the two main groupings it is found that while the calves were receiving milk, grain and hay, they consumed 25.7 pounds of whole corn and oats for each pound of the ground grains, while the ratio was only 0.7 pound of the whole grains per pound of ground grains when the heifers were getting grain and were on pasture or being fed silage and alfalfa. At no time however, were ground oats consumed in appreciable amounts and it was only toward the end that whole oats were eaten in considerable quantities.

TABLE 51

Average live weights and body measurements

TIME	LIVE WEIGHT	HEIGHT	DEPTH	WIDTH
	pounds	*inches*	*inches*	*inches*
Birth	68			
Start of trial	80	28.1	11.3	6.2
End of period:				
I	113	29.6	12.5	7.4
II	155	31.6	14.0	8.2
III	220	34.3	15.6	9.3
IV	278	35.9	16.4	10.5
V	321	37.8	17.6	11.3
VI	398	39.4	18.7	12.1
VII	469	41.0	19.9	13.3
VIII	515	42.1	20.7	13.7
IX	568	42.9	21.5	14.4
X	622	43.7	22.2	15.2
XI	677	44.5	22.6	15.6
XII	733	45.2	23.0	16.0
XIII	787	46.0	23.8	16.4
XIV	842	46.8	24.2	17.2
XV	854	47.6	24.6	17.6
XVI	905	48.0	25.4	17.9
XVII	954	48.4	25.7	18.3
XVIII	984	48.8	25.7	18.7
XIX	973	49.1	25.7	19.1
XX	990	49.5	26.1	19.1
XXI	991	49.5	26.1	19.1
XXII	972	49.5	26.5	19.1

TABLE 52

Percentage increase in live weight and body measurements

AGE	HEIFERS FED NORMALLY				HEIFERS ON SELF-FEEDER			
	Live weight	Height	Depth	Width	Live weight	Height	Depth	Width
months	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
6	309	34	57	67	372	35	56	82
12	731	54	92	118	896	58	100	155
18	988	64	112	146	1303	72	127	195
23	1171	68	121	164	1622	76	135	208

The average live weights of the heifers from the time of birth to the finish of the trial are given and the body measurements from the beginning of the trial. The calves used in this work

were practically 1 month of age when the work was started and in order to get an idea of their relative rates of growth, they are compared with calves fed under normal conditions. This comparison is made on the percentage increase in live weight from birth and body measurements from one month of age. This method was used in paper III of this series and the averages for the normally fed animals used in the work reported in that paper are used as a basis of comparison for the animals discussed here.

The calves used in the self-feeder trial were slightly below normal in live weight and body measurements at the start but they gained rapidly and at the end of the twenty-second period of the trial, when the self-fed heifers were 23 months of age they showed greater development in weight and all body measurements except

TABLE 53

Relative increase in growth of self-fed heifers as compared with normally grown heifers

AGE	LIVE WEIGHT	HEIGHT	DEPTH	WIDTH
months	*per cent*	*per cent*	*per cent*	*per cent*
6	101	103	98	122
12	123	107	109	131
18	131	113	113	134
23	130	112	111	127

width than the normally fed heifers did at the age of freshening, namely, 29 months. Their growth in weight and body measurements at the first of the trial greatly exceeded that for the normally fed heifers.

For further comparison the relative increases in live weight and body measurements of the self-fed heifers are compared with the same increases for the normally fed animals by 6 months periods. In other words, the average percentage increase in live weight of the self-fed heifers during their first 6 months is expressed as a percentage of the average percentage live weight increase during their first period of 6 months for the normally fed animals.

On examining the data by this method it is found that on the whole the self-fed heifers increased relatively more rapidly in live weight than they did in body measurements. This indicates in the best possible way the tendency for the self-fed heifers to

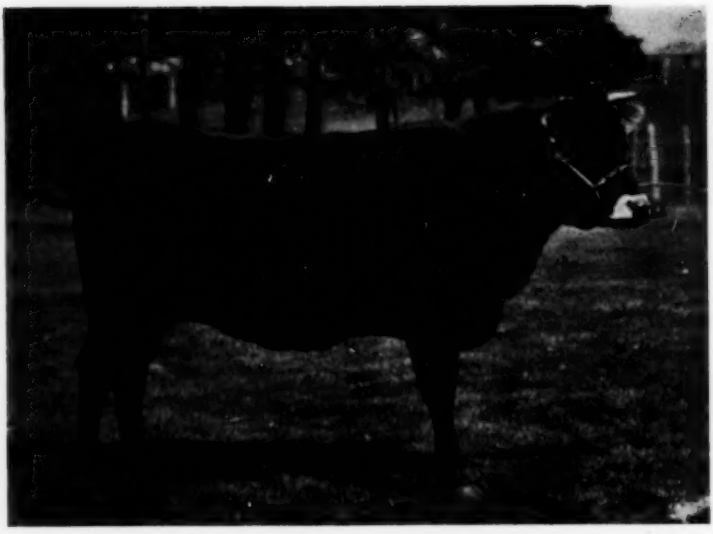

FIG. 1. HEIFER 487 AT 15 MONTHS OF AGE

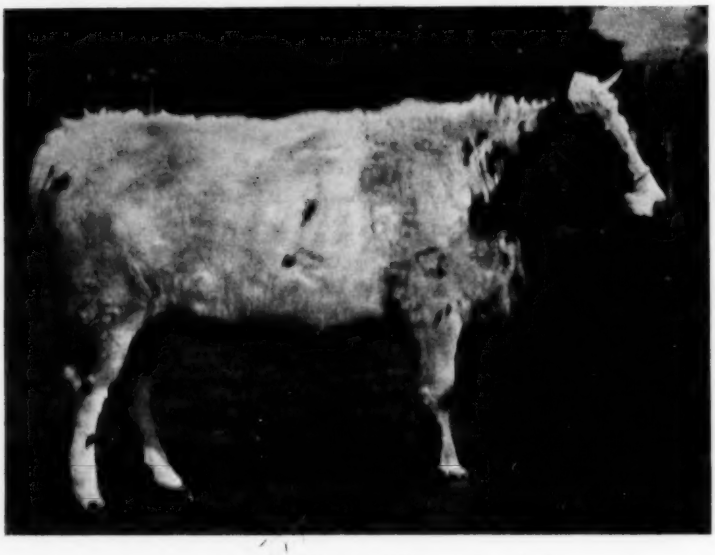

FIG. 2. HEIFER 491 AT 15 MONTHS OF AGE

lay on fat and get in higher condition than the normally fed animals.

When the body measurements alone are considered it is found that the greatest relative increase is in the width at the hooks and of the three measurements taken, this is the one most easily affected by condition. The height at withers and the depth of chest do not seem to be affected to such a great degree. All the body measurements were above normal, due to some extent

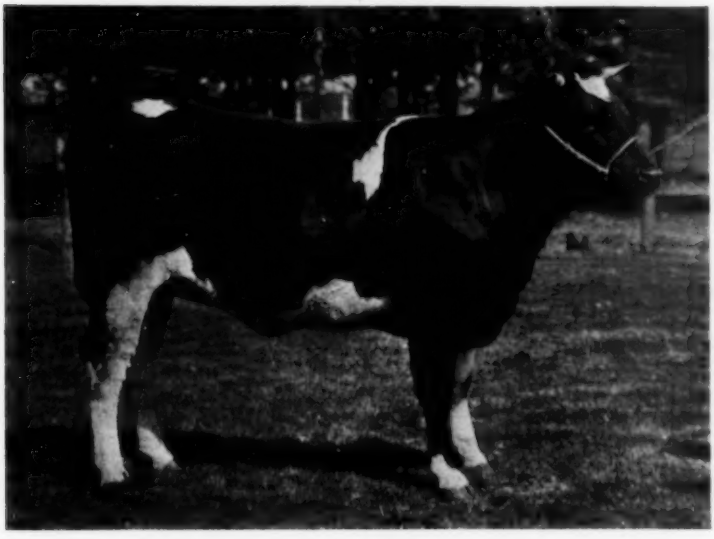

FIG. 3. HEIFER 493 AT 15 MONTHS OF AGE

to extra fleshing at the hooks, over the withers, and on the floor of the chest, but also undoubtedly to some extent due to increased skeletal growth.

It should be noted that from 18 to 23 months of age there was a falling off in the relative increases in the live weights and body measurements of the self-fed heifers. This was due to the fact that during the latter part of this period the heifers were on pasture only and lost in live weight and the outward evidences of condition.

The feed cost of growing the self-feeders has been determined with the same feed costs as were used in paper IV of this series in determining the cost of growing heifers fed normally. The costs of growing the normal heifers to 24 months of age are given as they were originally calculated on that basis while the feed cost for the self-fed heifers is given to 23 months—the age of the heifers when the trial finished.

The feed costs of growing the normal and self-fed heifers do not vary as widely as might be expected, up to 18 months of age, but from there to the age of 23 or 24 months there is a difference which needs explanation. In the first 6 months of life the calves, as would be expected, show practically the same indi-

TABLE 54

Average feed cost of growing heifers

AGE	FEED COST BY 6-MONTH PERIODS		CUMULATIVE FEED COST		FEED COST PER POUND OF GAIN BY 6-MONTH PERIODS		CUMULATIVE FEED COST PER POUND OF GAIN	
	Normal	Self-fed	Normal	Self-fed	Normal	Self-fed	Normal	Self-fed
months	*dollars*	*dollars*	*dollars*	*dollars*	*cents*	*cents*	*cents*	*cents*
0–6	35.57	35.81	35.57	35.81	14.4	14.1	14.4	14.1
6–12	20.18	21.78	55.75	57.59	8.3	6.1	11.4	9.5
12–18	17.76	20.92	73.51	78.51	10.3	7.6	11.1	8.9
18–24	16.27		89.78		9.4		10.7	
18–23		8.72		87.23		48.4		9.6

vidual feed costs, but in the two succeeding 6 months periods, the self-fed heifers ate relatively more grain per head and so at 18 months of age the total feed cost of growing the normal heifers was $73.51 and that for the self-fed heifers was $78.51 or $5 per head more. Up to this time the cost per pound of gain for the self-fed group was below normal, that for the normally fed heifers being 11.1 cents per pound and that for the self-fed animals 8.9 cents per pound. In paper IV of this series the heifers were divided into winter and summer groups, according to the time at which they were dropped. As the self-fed heifers were in the winter group it is well to state that the normal cost per pound of live weight gain up to 18 months of age was 11.4 cents for the winter group.

From 18 to 24 months of age the feed cost for normally fed heifers was $16.26 while the feed cost for the self-fed heifers was $8.72. This marked difference in favor of the self-fed animals is due in great part to fact that in the latter part of this stage the self-fed animals were on pasture alone, while the other animals had been receiving grain. The normally fed winter heifers during the period of from 18 to 24 months of age had an average feed cost of $15.16.

From the age of 18 to 23 months the self-fed heifers showed little live weight gain, in fact at 23 months of age they weighed

TABLE 55

Breeding of heifers

HEIFER NUMBER	DATES OF BREEDING	DATE OF SUCCESSFUL BREEDING	FRESH	CALF		AGE AT FRESHENING
				Sex	Weight	
					pounds	*months*
487	12/10/20					
	1/ 2/21	1/2/21	9/28/21	F	41	25
491	1/ 2/21					
	1/23/21					
	3/ 3/21	3/3/21	12/ 9/21	M	75	27
493	2/26/21					
	4/ 5/21					
	7/ 6/21					
	8/ 7/21	8/7/21				32
Average.....	3					28

less than they did at 19 months of age. This is due to the fact that when grain was taken away from them completely and they were left to subsist on young grass alone, a considerable amount of shrink occurred and this had not been completely overcome at the end of the trial. Consequently, the feed cost per pound of gain during the last 5 months is exceptionally high. On the average the feed cost per pound of live weight gain from birth was 9.6 cents in the case of the self-fed heifers at 23 months of age and 10.7 cents per pound in the case of the normally grown heifers at 24 months of age.

There is apparently some difference in the feed cost per hundred pounds of live weight gain between heifers fed in the ordinary method and those self-fed. This is true when they reach the age of about 2 years and the self-feeder would appear to have other advantages as the animals raised by this method need less attention when they have passed weaning age and grow heavier and larger.

In connection with the work with the heifers raised with the self-feeder a record was kept of the breeding of the animals and as was noted earlier the trial was discontinued owing to apparent difficulty in getting them bred.

The heifers, nos. 487 and 491, were settled during the trial but owing to their condition it was a difficult matter to tell, in the early stages, whether or not they were pregnant. Later on, on examination, per rectum, they proved to be in calf. They freshened at ages which are normal for the breeds to which they belong. The heifer 487 was a Jersey, freshening at 25 months of age, and no. 491, an Ayrshire, freshening at 27 months. Throughout the trial the Jersey heifer was in relatively lower condition than the Ayrshire. The Holstein heifer, no. 493, was in the highest condition throughout the trial. As yet she has not freshened but on examination, per rectum, has shown that she is going to freshen to the breeding of August 7, 1921. This means that she will freshen at 32 months of age—a rather advanced age for a heifer of her development.

The animals were of different breeds and this induces a factor beyond control, but there should not be much difference in the freshening ages of Ayrshires and Holsteins and it can readily be seen that there was much more difficulty in getting the Holstein settled and this is very probably due to the exceedingly high condition she was in. She was only bred successfully after she had been on pasture alone for some time and lost in condition.

SUMMARY

From this trial with a self-feeder in the raising of dairy heifers it is probable that the following suggestions may be made:

1. There is little difference in the feed cost of raising heifers to two years of age by the self-feeder method or by hand feeding where a liberal grain allowance is given.

2. The feed cost per pound of gain is lower with the self-fed heifers.

3. The heifers raised with the self-feeder will show the greater increases in live weights, height at withers, depth of chest and width.

4. The greatest relative increase will be in the live weight and though the skeletal measurements mentioned do show a true increase, this is further augmented by extra fleshing.

5. With self-fed heifers the extra conditioning may tend to delay breeding, or perhaps impair their breeding powers.

6. Ground oats and wheat bran are not palatable to heifers.

7. When the heifers are on a milk ration, whole corn is the grain consumed in greatest quantities; cracked corn and whole oats being used but little.

8. After weaning, and when under summer conditions, the consumption of cracked corn increased while that of whole corn decreased.

9. When the heifers were under winter conditions, after they were a year old, cracked corn and whole oats were apparently the most palatable grains.

10. Linseed oil meal was evidently a palatable supplement though the quantities of it consumed varied from time to time.

11. Salt was consumed regularly. The largest amounts were used when pasture was available.

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A STUDY IN HERD EXPANSION

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Recently we have had the privilege of studying records of a herd of dairy cattle that was established in 1896, twenty-seven years ago. To found the herd 14 nice cows were purchased and ever since then the best heifer calves have been retained to enlarge and improve the herd.

Like every other herd, this one has been visited by its quota of abortions, tuberculosis, accidents and defectives, but it has received unusually good attention, care, feed and stabling. We believe its rate of expansion, or growth, will prove interesting to breeders of cattle. A review of this herd is as follows:

1896—Herd founded with 14 cows.

1912—The herd in 1912 contained 29 female descendents of the 14 cows. Eleven of the 14 foundation cows failed to produce enough offspring, particularly heifers, to breed on and disappeared from the herd in the sixteen years, while 3 prolific cows are responsible for the herd growth.

1922—The herd in 1922 contained 37 females, all descendants of the 29 females of 1912.

During the twenty-six years an effort has been made to enlarge and improve the herd by retaining the best heifers, the bull calves being sold. The herd growth was not rapid, having been held in check by such difficulties as deaths, accidents, tuberculosis, infertility, defects that caused the culling out of individuals such as sway backs, and loss of quarters of udders. These difficulties are met by all breeders of livestock, but this herd has been fortunate as no wholesale disaster has ever hit this herd, such as sometimes happens.

During the first sixteen years the females worthy of retention slightly more than doubled the size of the herd, while during the next ten years the herd increased from 29 to 37 females, an

increase of 8 females. During twenty-six years the herd increased from 14 foundation cows to a herd of 37 females. Twenty-six of the 37 trace to one extra prolific cow that was among the 14 "originals."

A STUDY OF HEIFERS PRODUCED FROM 37 COWS DURING A FIVE YEAR PERIOD

A study of this herd covering five years, with 37 cows, shows that they produced during that period 151 calves, of which 61 were heifers. Therefore, 30.2 cows calved each year, with 6.8 cows barren each year, a percentage of 23 per cent barren. That is 30.2 cows calved every year, and 6.8 failed to calve, but they did calve irregularly. There were no infertile cows in the herd.

Female progeny of 37 cows in five years

37 cows produced 151 calves in five years (90 bulls and 61 heifers)
Average of 30.2 calves annually from 37 cows
Per cent of barren cows, 23 per cent

Growth of 61 heifer calves

61 heifer calves
- 7 aborted dead or weak and killed

54 living heifers at birth
- 11 weak heifers vealed under six months old

43 strong six months old heifers
- 3 good heifers sold to other breeders
- 4 good heifers became defective
- 4 good heifers died

32 good two year old cows
- 4 reacted
- 5 had accidents

23 good three-year-old cows

This herd of 37 cows produced in five years 151 calves, of which 90 were bulls and 61 heifers. Seven of the heifers were aborted and 11 were weak or so inferior as to be vealed before they were six months old, leaving 43 good strong heifers, or an average of 1.13 good strong six months old heifers per cow in five years.

While they were under two old years the owner of the herd sold 3 heifers to other breeders of dairy cattle and sold to butcher 4 heifers that had become inferior, aborted or had bloated and been stuck, which always deteriorates an animal, or that had become out of condition. Four heifers died under two years old.

Some breeders try to rear every living heifer that is born. There were 54 living heifers born in this herd in the five years, 7 of the 61 were aborted dead. Figuring on the basis of the 54 living heifers, 32 grew into good two-year-old cows, a ratio of 54 heifers to 32 cows, or 59 per cent. But we prefer to figure on the basis of the 43 good strong heifers. These 43 strong six-month-old heifers grew into 32 good two-year-old milk cows, a percentage of 74.5 per cent, or about 7 good young cows raised from 10 good heifer calves. But 4 of these young cows reacted and 5 had accidents, such as injury to udder, abortions, etc., to befall them and were culled out. This left this breeder 23 good three-year-old cows from his crop of 54 living heifer calves, or from his crop of 43 good six-months-old heifers.

THE ACIDITY PHASE OF THE ICE CREAM MIX[1]

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The success of ice cream making is wholly dependent upon the preparation and handling of the ice cream mix. Recent experiments have pointed out the desirability of aging the mix for twenty-four to seventy-two hours (1). The primary object of aging is to increase the viscosity of the mix which aids considerably during the process of freezing in as much as it favors the incorporation of air into the ice cream and less time is consumed in whipping up the mix to the desired overrun than in the case of a fresh mix (2). The viscosity of the aged ice cream mix is influenced by several factors. What rôle does acidity play in the ice cream mix?

At the time this experiment was inaugurated no analytical work dealing with the acidity phase of the ice cream mix was on record with the exception of the following statements made in publications on ice cream making.

The acidity of the cream has no effect on the swell of the ice cream produced, until it reaches such a point as to cause the cream to become brittle, when a lessened yield will result. Either natural, or added commercial lactic acid seems to improve the body and texture slightly. A cream containing 0.50 per cent or even 0.60 per cent acid will make a good looking and good feeling ice cream and except for the sour taste, will be as satisfactory an article as could be desired (3).

The development of a small amount of lactic acid in the ice cream mix may have a pronounced effect in increasing the overrun. The development of a large amount of acid does not seem to materially increase the overrun and of course, it may be detrimental to the flavor of ice cream (4).

[1] A part of the "Study of the principles of ice cream making." This material is based on a thesis presented to the faculty of the Graduate School of the University of Nebraska by Benjamin I. Masurovsky in the degree of Master of Science in Dairy Husbandry.

[2] Adams Fund Project 105, under direction of H. P. Davis, University of Nebraska, Agricultural Experiment Station, Lincoln, Nebraska.

The acidity is an important factor in obtaining the most desirable flavor and texture in the finished product and in controlling the overrun. An acidity of between 0.25 and 0.30 per cent is considered as giving best results. The presence of too much acid may cause the mix to curdle, particularly where the same is pasteurized. The acidity may be immediately increased by adding cultured buttermilk when compounding the mix. This will insure a good sharp flavor; permit of pastuerization thus insuring a low bacteria count, and make it possible to produce a mix of constant and ample viscosity. Possibly the aging period in the case of mix treated in this manner can be shortened or dispensed with. This is a phase of the ice cream industry that is in its infancy, and it opens possibilities for very interesting studies (5).

With this scant information regarding the acidity phase of the ice cream mix and its importance in ice cream making it was difficult to start consistent work pertaining to this problem. The experiments reported in this manuscript give the results obtained in preliminary work dealing with the titratable acidity, H-ion concentration, and buffer action of the ice cream mix and the findings throw some light on this subject which will, doubtless, facilitate the organization of a systematic series of experiments on the relation of acidity to the various essential factors involved in the manufacturing of commercial ice cream.

EQUIPMENT

1. Fifty gallon vat pasteurizer "Wizard" provided with a rotary coil. Creamery Package Co.
2. "Progress" homogenizer—capacity 90 gallons per hour. Davis-Watkins Co.
3. Two section surface tubular cooler, each section measuring 50 by 18 inches. Cooled by cold brine. Creamery Package Co.
4. Forty quart freezer—"Perfection Brine Freezer." J. G. Cherry Co.
5. "De Raef"—Ice Cream Weight Standardizer, made by N. A. Kennedy Supply Co.
6. Scott's viscosimeter.
7. MacMichael viscosimeter.

8. Type K outfit of Leeds and Northup Co., with Bailey's hydrogen electrode.

9. "Mojonnier Tester" for the determination of total solids and butterfat. Mojonnier Brothers.

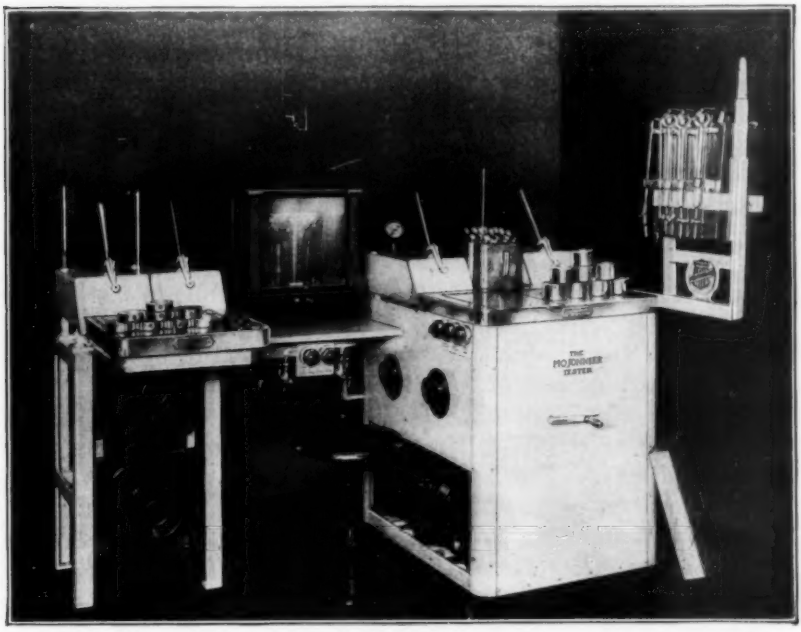

FIG. 1. MOJONNIER TESTER USED FOR THE DETERMINATION OF TOTAL SOLIDS AND BUTTERFAT IN THE EXPERIMENTAL ICE CREAM MIXES

DESCRIPTION OF METHODS

Procedure I: Preparation of ice cream mix. The cream was standardized to the desired butterfat content by addition of pasteurized sweet skim milk and sometimes salted butter was used to provide the additional requirement of butterfat. The milk-solids-not-fat were derived from powdered skim milk (Merrell-Soule) dissolved in the sweet skim milk. The standardized cream was heated to about 140°F. when the dry powdered gelatin

(high grade) thoroughly mixed with the granulated sugar was added. The entire mix was then pasteurized at 145°F. held for thirty minutes and afterwards homogenized at a pressure of 2000 to 2500 pounds per square inch, followed by cooling to about 50°F.

In the case of a stock batch only 85 per cent of the mix was pasteurized and homogenized while the 15 per cent usually was equivalent to sweet skim milk which was added later as desired in the experiment under consideration.

The aging of the ice cream mix was taking place in 10-gallon cans at a temperature of 40° to 45°F.

Procedure II: Determination of titratable acidity. The sample of ice cream mix was kept in a water bath until a temperature of 20°C. was reached. 18 grams of the sample was weighed out into a porcelain dish and diluted with 50 cc. of distilled water. This preparation was thoroughly mixed before titration. The titratable acidity of the mix was determined by the required amount of N/10 NaOH using 5 drops of phenolphthalein as an indicator. The acidity was expressed in cubic centimeters of N/10 NaOH required to neutralize 18 grams of ice cream mix. (This procedure enables one to estimate readily the percentage of titratable acidity by dividing the number of cubic centimeters of N/10 NaOH by 20.)

Procedure III: Determination of pH value. The H-ion concentration was determined electro-metrically on Leeds and Northup Type K potentiometer using Bailey's electrode, saturated KCl calomel cell, and saturated KCl in connecting vessel. The hydrogen electrode was rinsed with some of the sample of the ice cream mix, then filled and saturated with hydrogen gas from a tank containing hydrogen gas manufactured by the Kansas City Oxygen Gas Company. The hydrogen electrode with content was shaken vigorously for two and a half minutes and readings taken on the potentiometer and the voltage converted into pH according to Schmidt-Hoagland tables(6).

Procedure IV: Estimation of buffer action. The sample of ice cream was tested for its pH value then 2 cc. of N/10 NaOH was added to 25 cc. of the original sample mixing it thoroughly

with the alkali and its pH value determined. The same procedure was carried out with all the samples of the same mix at different aging intervals.

Procedure V: The determination of viscosity by the use of Scott's viscosimeter. The sample of the ice cream mix was tampered to 20°C. thoroughly mixed and 100 cc. of it was placed in the viscosimeter. Readings were taken at 20°C. The number of

FIG. 2. SCOTT'S VISCOSIMETER SERVED AS A MEANS OF INDICATING THE COMPARATIVE VISCOSITIES OF THE ICE CREAM MIXES UNDER EXPERIMENTATION

cubic centimeters of mix delivered into a 50 cc. graduated glass cylinder in 25 seconds was used as the "viscosity index" for comparing results obtained from the various samples under consideration.

Procedure VI: Determination of viscosity by MacMichael's method. MacMichael's viscosimeter was used having the cylindrical bob attached to wire No. 30. The sample of ice cream was tempered to 20°C., and delivered into the standard diameter cup until it reached the fourth mark on the bob. The turn table was adjusted to make 20 revolutions in about sixty-two seconds. Readings were taken when the pointer was at its slightest deflection and interpreted in degree of M.

Procedure VII: Determination of butterfat in ice cream mix. The Roese-Gottlieb fat method was used with modifications as required by Mojonnier. The Mojonnier tester was used in this work. The sample was thoroughly mixed and tempered to 20°C. About five grams of the sample was weighed out by means of weighing pipettes and delivered into the extraction flasks.

For the first extraction, 6 cc. of distilled water, 1.5 cc. of NH_4OH, 10 cc. of alcohol and 25 cc. each of ethyl and petroleum ethers were used. After adding water the sample was shaken vigorously and again after adding the ammonium hydroxide, and one-half minute each after adding the alcohol and the two ethers.

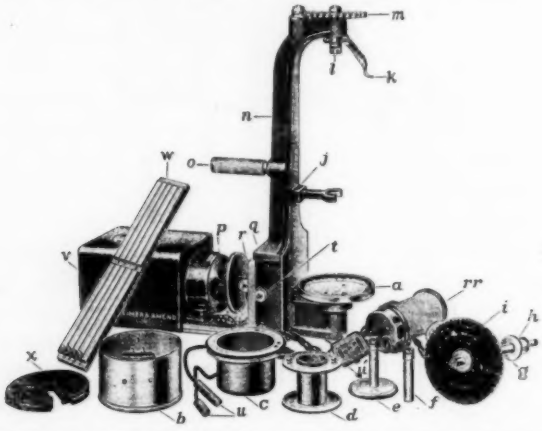

FIG. 3. MACMICHAEL VISCOSIMETER USED FOR MEASURING THE VISCOSITY OF ICE CREAM MIXES DURING AGING

The extraction flasks with their content were placed in the centrifuge and whirled for one minute. The ether extract was then decanted into aluminum dishes of constant weight.

For the second extraction 5 cc. of alcohol, 25 cc. each of ethyl and petroleum ethers were added and the content was shaken for twenty seconds after the addition of each reagent. The centrifuging lasted for thirty seconds. The ether extract was again decanted into the same aluminum dish containing the first extraction. After evaporating off the ether, the dish with the fat

was heated in the vacuum oven at 135°C. for five minutes with about 22 inches of vacuum, then placed in the cooling desiccator at room temperature for seven minutes. The percentage of butterfat was calculated from duplicate determinations.

Procedure VIII: Determination of total solids of ice cream mixes. The Mojonnier tester was employed in this work. Duplicate samples, about 1 gram each, were weighed out into the "solids dishes" of the known constant weight. About 1 cc. of distilled water was added to the ice cream mix in the dish mixing and distributing the content evenly on the bottom of the dish and placed upon the solids hot plate. After evaporation the dish was transferred to the solids oven and dried in the oven under 22 inches vacuum for ten minutes. Then the solids dish was transferred to the cooling desiccator for five minutes.

Experiment I. On September 27, 1922, at 4 p.m. the following procedure was carried out in preparing an ice cream mix.

Five pounds of powdered skim milk were dissolved in 10 gallons of sweet skim milk at a temperature between 85° to 95°F. 139 pounds of sweet cream testing 35 per cent butterfat were placed in a pasteurized vat equipped with a horizontally rotating coil. The required amount of 190 pounds of sweet skim milk was added including the 10 gallons of skim milk containing the dissolved 5 pounds of powdered skim milk. When the temperature of the vat content reached 100°F. 8 pounds of salted butter was placed into the vat and shortly after the melting and thorough incorporation of the butterfat 56 pounds of sugar and 2 pounds of gelatin mixed were added to complete the mix requirements. The pasteurization took place at 145°F. for thirty minutes. It was run through a homogenizer at a pressure between 2000 and 2500 pounds per square inch and cooled to about 45°F. The homogenized ice cream mix was placed in sterilized 10-gallon cans set in the "aging" room where it was kept at a temperature below 40°F.

On September 28, 1922, at 10 a.m. a representative sample of the mix under consideration was taken and tested for its butterfat content and total solids using the Mojonnier outfit. It tested 13.75 per cent butterfat and 36.7 per cent total solids.

In order to raise the titratable acidity of the mix more rapidly the following preliminary test was made: 9.5 pounds of the mix were placed into each of four "shot-gun" cans numbered 1, 2, 3 and 4.

Then 0.5 pound of "lactone starter"[3] testing 16.7 cc. N/10 NaOH or 0.835 per cent lactic acid was added to each of the cans numbered 1, 2, and 3 and 0.5 pounds of pasteurized whole milk was added to can 4 which was used as a check in this experiment. Dairy thermometers were placed in each of the prepared mixes in the "shot guns" and held at different temperatures: can 1 was kept at room temperature, between 60 to 75°F., can 2 and check, can 4 at the temperature of the aging room, 40 to 45°F., can 3 was held at a temperature of 50°F.

The results obtained are given below.

DATE	NUMBER OF CAN	TIME	TEMPERATURE	ACIDITY IN CC. N/10 NaOH	ACIDITY IN PER CENT OF LACTIC ACID
			°F.		
September 28	1	10 a.m.	51	3.4	0.17
September 28	1	3 p.m.	60	3.5	0.175
September 29	1	11 a.m.	75	15.4	0.77
September 28	2	10 a.m.	51	3.4	0.17
September 28	2	3 p.m.	42	3.3	0.165
September 29	2	11 a.m.	44	3.3	0.165
September 28	3	10 a.m.	51	3.4	0.17
September 28	3	3 p.m.	50	3.3	0.165
September 29	3	11 a.m.	50	5.0	0.25
September 28	4	10 a.m.	51	2.6	0.13
September 28	4	3 p.m.	42	2.5	0.125
September 29	4	11 a.m.	44	2.5	0.125

On September 29, 1922, at 3 p. m. the above samples of acidified mix were combined with sufficient of the unacidified mix to make up 45 pounds of ice cream mix the acidity of which was 5.9 cc. N/10 NaOH or 0.295 per cent lactic acid. It was frozen in a 25-quart Cherry freezer and with the addition of 4 ounces of caramel made into ice cream.

[3] Lactone starter is prepared of whole milk inoculated with Ericsson's Butter Culture.

TABLE 1

DATE	NUMBER OF BATCH	NUMBER OF EXPERIMENT	AGING	AMOUNT FROZEN	WEIGHT OF GALLON OF MIX	TEMPERATURE OF MIX	VISCOSITY INDEX	ACIDITY REQUIRE N/10 NaOH	TEMPERATURE OF BRINE	BRINE ON	DE BAEF READING	BRINE OFF	DE BAEF READING	BRINE ON	DE BAEF READING	OVERRUN	REMARKS
			hrs.	*lbs.*	*lbs.*	*°F.*		*cc.*	*°F.*	*min.*	*lbs. per gal.*	*min.*	*lbs. per gal.*	*min.*	*lbs. per gal.*	*per cent*	
September 29.....	2a	1	43	45	8.85	44		2.4	2.0	12	5.5	7	4.85			82	
September 29.....	2b	1	43	45	8.85	44		5.9	2.0	12	5.6	8	4.75			86	
October 18.....	3a	2	72	45	9.0	41		2.6	3.0	10.5	4.85	7.5	4.60			95	Aged with starter or twenty-four hours
October 18.....	3b	2	72	45	9.0	41		7.5	4.0	10.5	4.75	7.0	4	3	4.5	100	
October 26.....	4a	3	19	42	8.85	48	6	2.3	3.0	10	5.50	8	4.50			98	
October 26	4b	3	19	42	8.85	48	4	7.0	3.0	10	5.0	8	4.25			110	
October 30.....	5a	4	3	44.5	8.70	60	12	2.4	5.0	10	5.85	9	4.85			76	
October 30.....	5b	4	3	44.5	8.70	57	5	4.7	5.0	9	5.75	9	4.75			84	
November 6.....	6a	5	3	44	8.70	57	11.5	2.5	7.5	10	5.60	7	4.35	2	4.35	100	Exceptionally smooth texture
November 6.....	6b	5	3	44	8.70	57	7	4.8	7.5	10	5.50	8	4.35	2	4.35	100	Exceptionally smooth texture
November 13.....	7a	6	2	44.5	8.70	59	11.5	2.3	7.0	10	5.70	10	4.50			94	
November 13.....	7b	6	2	44	8.70	56	4.5	4.9	7.0	10	5.35	10	4.50			94	
November 15.....	8a	7	48	42.5	8.70	58	4.0	2.4	4.0	8	5.50	10	4.35			100	
November 15.....	8b	7	48	42.5	8.70	59	4.0	2.4	4.0	9	5.60	12	4.35			100	
November 15.....	9a	7	48	41.0	8.70	60	5.5	2.5	4.0	9	5.70	12	4.35			100	Aged for twenty-four hours with additional skim milk
November 15.....	9b	7	48	40.5	8.70	59	2.3	5.35	4.0	9	5.70	14	4.35			100	Aged for twenty-four hours with starter
December 8.....	10a	8	72	41.0	8.35	38	6.0	2.5	2.0	7	5.50	11	4.25			97.1	
	10b	8	72	41.0	8.25	40	5.2	2.4	3.0	8	5.60	15	4.12			100	Aged for twenty-four hours with additional skim milk
	10c	8	72	41.0	8.50	40	2.3	5.3	4.0	8	5.50	16	4.25			100	Aged for twenty-four hours with additiona' starter

The lactone flavor was somewhat noticeable shortly after drawing the ice cream from the freezer but on hardening the blending of the caramel and lactone flavor became more agreeable to the palate.

For data during freezing see table 1 under batches 2a and 2b.

Experiment II. On October 15, 1922, at 11 a.m. a 400-pound mix of the following composition was pasteurized at 145°F. for thirty minutes and homogenized at 2000 to 2500 pounds pressure per square inch:

	pounds
Cream testing 17.5 per cent butterfat	329
Powdered skim milk	5
Butter (salted)	8
Sugar (granulated)	56
Gelatin	2

Total of 400 pounds testing 14.4 per cent butterfat and 36.7 per cent total solids

This mix was held in 10-gallon cans at 40° to 45°F. until October 17, 11 a.m. when the following modification was made. To 59 pounds of the original mix 9 pounds of raw cream, testing 43.5 per cent butterfat, was added; also, 23 pounds of whole milk starter and 4.5 pounds of sugar. The acidity of the starter was 15.8 cc. N/10 NaOH or 0.79 per cent lactic acid and the original mix had an acidity of 2.65 cc. N/10 NaOH or 0.13 per cent lactic acid. On October 18, 1922, at 9 a.m. the freezing of batches 3a and 3b took place. (See table 1.) The acidity of the modified mix was 7.5 cc. N/10 NaOH. There was less viscosity, at sight, in batch 3b and a tendency to swell was more noticeable than in case of batch 3a.

This time 4 ounces of vanilla flavoring was used in each batch. The lactic acid flavor persisted even during the hardening process.

Experiment III. On October 25, 1922, at 4 p. m. a stock batch was prepared so as to fulfill the desired composition when 15 per cent skim milk starter[4] or sweet skim milk is added to it. The composition of the stock batch follows:

[4] Skim milk starter was prepared from sweet skim milk inoculated with Ericsson's Butter Culture.

60.5 pounds of cream testing 45 per cent butterfat
78.5 pounds of skim milk
2.25 pounds of powdered skim milk
28.0 pounds of granulated sugar
1.0 pounds of gelatin

170.25 pounds of stock batch testing 16 per cent butterfat and 40.11 per cent total solids

The stock batch was pasteurized at 145°F. for thirty minutes; homogenized at 2000 to 2500 pounds pressure per square inch and cooled at 52°F.

To 73 pounds of the homogenized stock batch 12 pounds of skim milk starter was added making a total of 85 pounds of mix to represent experimental batch 4b; to another 73 pounds of the stock batch 12 pounds of raw sweet skim milk was added making 85 pounds of mix used as batch 4a. Both batches, 4a and 4b were aged for nineteen hours.

From a study of table 1 it is apparent that the 0.35 per cent lactic acid in batch 4b helped to increase viscosity of the mix before and during aging and later during freezing facilitated in obtaining "overrun."

Experimental batch 4a tested 12.8 per cent butterfat 14 per cent sugar and 35.75 per cent total solids. Batch 4b tested 12.8 per cent butterfat, 4 per cent sugar and 36.12 per cent total solids.

Experiment IV. On October 30, 1922, at 11 a.m. a stock batch of the following composition was prepared:

60.0 pounds of sweet cream testing 47.5 per cent butterfat
80.0 pounds of sweet skim milk
2.25 pounds of powdered skim milk
1.0 pounds of gelatin
28.0 pounds of granulated sugar

171.25 pounds of stock batch testing 16.5 per cent butterfat and 40.5 per cent total solids

The process of pasteurization, homogenization and modification of the mixes were similar to those performed in experiment III with the exception that batches 5a and 5b were aged for three hours instead of nineteen hours as in the preceding experiment.

Examining data in table 1, we find that the addition of skim milk starter to form batch 5b raised the viscosity as well as the acidity of the mix. The results obtained during freezing indicate that a slight gain in time is made to reach a certain point of overrun when the brine is on, but the total time of freezing is about the same for batch 5b as for batch 5a. Another point worth noticing is that no gain in overrun is obtained when the increase of viscosity is due to a rise in acidity and not aging.

Experiment V. On November 6, 1922, at 11 a.m. the following stock batch was prepared:

138.0 pounds of cream testing 41 per cent butterfat
142.0 pounds of sweet skim milk
4.5 pounds of powdered skim milk
56.0 pounds of granulated sugar
2.0 pounds of gelatin

342.5 pounds of stock batch testing 16.5 per cent butterfat and 40.2 per cent total solids

To 73 pounds of stock batch 12 pounds of pasteurized sweet skim milk was added making up 85 pounds of experimental batch 6a and to another 73 pounds of the stock batch 12 pounds of skim milk starter was added to make 85 pounds of batch 6b.

Composition of batches 6a and 6b

	AMOUNT	BUTTERFAT	SUGAR	MILK-SOLIDS-NOT-FAT	GELATIN	TOTAL SOLIDS
	pounds	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Batch 6a	85	14.04	14	8.26	0.5	36.80
Batch 6b	85	14.35	14	7.92	0.5	36.77

The handling of the stock batch and its modification for the preparation of batches 6a and 6b were similar to those described in experiment IV.

A study of table 1 shows that during the process of freezing batches 6a and 6b the results were identical although there was a difference in the viscosity and acidity of the batches used. Furthermore, there appears to be no necessity for prolonged aging of an ice cream mix to insure a 100 per cent swell provided proper

care is taken during pasteurization and homogenization of the ice cream mix properly composed.

Experiment VI. On November 13, 1922, at 11 a.m. a stock batch was prepared consisting of the following ingredients:

123.5 pounds of cream testing 45.5 per cent butterfat
156.0 pounds of sweet skim milk
5.0 pounds of powdered skim milk
56.0 pounds of granulated sugar
2.0 pounds of gelatin

342.5 pounds of stock batch testing 16.5 per cent butterfat and 40.2 per cent total solids

This ice cream mix was pasteurized at 145°F. for thirty minutes, homogenized at 2000 to 2500 pounds pressure per square inch and cooled to 54°F. Immediately after cooling the homogenized mix 12 pounds of pasteurized sweet skim milk was added to 73 pounds of stock batch forming 85 pounds of batch 7a and to another 73 pounds of stock batch 12 pounds of skim milk starter was added making up 85 pounds of batch 7b.

Composition of batches 7a and 7b

	AMOUNT	BUTTERFAT	SUGAR	MILK-SOLIDS-NOT-FAT	GELATIN	TOTAL SOLIDS
	pounds	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Batch 7a.....	85	14.28	14	7.72	0.5	36.5
Batch 7b.....	85	14.28	14	7.72	0.5	36.5

These two batches were frozen at 2 p.m. November 13, 1922. From a study of table 1 it is noticed that the addition of skim milk starter raised the viscosity as well as the acidity of batch 7b. There appeared to be, however, no significant difference in results obtained during the freezing process save a slight gain in time in favor of batch 7b in reaching a greater overrun in the same number of minutes while the brine was on.

Experiment VII. On November 15, 1922, at 10 a.m. experimental batches 8a and 8b were prepared by adding 12 pounds of pasteurized sweet skim milk to 73 pounds of stock batch which has been used in the previous experiment. At the time this

addition was made the stock batch had been aged for forty-eight hours.

On November 14, 1922, at 10 a.m. batch 9a was prepared by adding 6 pounds of pasteurized sweet skim milk to 36.5 pounds of stock batch made on November 13 and which had been aged for twenty-four hours.

Similarly batch 9b was prepared except that 6 pounds of skim milk starter was taking the place of the pasteurized sweet skim milk. Both batches, 9a and 9b were aged for twenty-four hours.

From a study of table 1 it is apparent that the difference in viscosity of the same ice cream mix does not influence the results obtained during freezing.

Experiment VIII. On December 5, 1922, at 11 a.m. the following stock batch was prepared:

95.0 pounds of sweet cream testing 44.3 per cent butterfat
113.0 pounds of sweet pasteurized skim milk
3.5 pounds of powdered skim milk
42.0 pounds of granulated sugar
1.5 pounds of gelatin

255.0 pounds of stock batch testing 16.4 per cent butterfat and 43.8 per cent total solids

Experimental batch 10a was prepared by adding 12 pounds of pasteurized sweet skim milk to 73 pounds of the above prepared stock batch and allowed to age at 40°F.

On December 7, 1922, the following experimental batches were prepared: to 73 pounds of stock batch obtained on December 5 and aged at 40 to 45°F. for forty-eight hours 12 pounds of pasteurized sweet skim milk was added thoroughly mixed and obtaining experimental batch 10b which was then aged for twenty-four hours.

Experimental batch 10c was prepared in the same way as 10b except that 12 pounds of skim milk starter was used instead of pasteurized sweet skim milk.

On December 8, 1922, at 3 p.m. the freezing of 10a, 10b and 10c took place. Examining table 1 it is apparent that in spite of different viscosities of the mixes there were no differences in the

results obtained during freezing. This substantiates the results obtained in experiment VII. It proves, further, that high viscosity obtained by increasing the acidity of the ice cream mix does not influence the yield to any noticeable extent as compared with a low viscosity of the same mix obtained through aging.

Experimeni IX To determine the H-ion concentration of some of the experimental batches the Bailey electrode was found to be satisfactory in this work. Samples of experimental batches were tested for viscosity and H-ion concentration simultaneously.

The following results were obtained:

DATE	TIME	NUMBER OF BATCH	VISCOSITY	pH VALUE	REMARKS
			°M.		
December 5.....	2 p.m.	10a	17.5	6.49	Normal mix
December 6.....	8 a.m.	10a	23.5	6.49	Normal mix
December 6.....	4 p.m.	10a	30.0	6.49	Normal mix
December 7.....	8 a.m.	10a	23.5	6.48	Normal mix
December 8.....	9 a.m.	10b	46.0	6.46	Modified after aging for forty-eight hours
December 8.....	9 a.m.	10c	60.0	5.76	Content 15 per cent starter

Experiment X. On December 11, 1922, 20 pounds of mix IIa was prepared in a "shot-gun" can by placing it in a water bath of 145°F. and by frequent agitation of the mix in the can pasteurization took place at 145°F. for thirty minutes, then, immediately cooled to about 50°F. and placed in the aging room at 42°F. The composition of this mix was 14 per cent butterfat, 14 per cent sugar, 1.2 per cent powdered skim milk and 0.5 per cent gelatin, and with a total solids of 35.9 per cent. Samples of this batch were tested for viscosity, pH value, amd buffer action.

The following results were obtained:

DATE	TIME	NUMBER OF BATCH	VISCOSITY	pH VALUE	BUFFER ACTION IN pH
			°M.		
December 11.....	12 n.	11a	5.5	6.46	7.15
December 11.....	3 p.m.	11a	9.5	6.46	7.16
December 12.....	9 a.m.	11a	194.0	6.46	7.16

CONCLUSIONS

A total of 839 pounds of ice cream mix were used for work in connection with experiments on the rôle of acidity in the manufacturing of ice cream.

The titratable acidity of the ice cream mix was raised by the addition of "starter" made from Ericsson's butter culture.

1. The addition of starter to the homogenized mix tends to increase the viscosity before and during aging.

2. Comparing the effects of a viscous mix produced by raising its titratable acidity and those due to aging it was found to give different results during the freezing process.

3. Comparing results obtained from a mix of high viscosity due to high acidity and a mix with a lower viscosity due to aging but of low acidity no decided differences were noticed during the freezing process.

4. There appears to be no change in the pH value of a normally handled ice cream mix during aging for twenty-four to forty-eight hours.

5. The buffer action is apparently undisturbed during the aging of an ice cream mix which has been prepared in a normal way.

6. Since the introduction of acidity imparts objectionable flavor in many ice creams and does not noticeably influence the physical make-up of the ice cream mix during aging and freezing it would not be good practice to use dairy products of high acidity in ice cream making, so far as practicability is concerned.

I wish to express my thanks to Dr. M. J. Blish, Head of the Agricultural Chemistry Department, for advice in connection with the H-ion concentration work, and to Prof. John A. Luithly, Head of the Dairy Manufacturing Department, for hearty cooperation and personal interest taken in these experiments.

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THE PROBLEM OF TRANSPORTING MILK IN HOT CONDITION

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Since glass-lined tanks mounted on railroad cars and automobile trucks have come into use for the transportation of milk, the question has again been raised as to whether milk could not be heated and kept hot during transportation and bacterial growth checked by heat rather than by refrigeration.

This is a logical question for an engineer to ask, for he is not expected to have any knowledge of the thermophilic types of bacteria. (The term thermophilic is used in its correct sense, meaning bacteria which grow at high temperature.) But the bacteriologist will at once think of these bacteria and will question the practicability of shipping the milk hot. However, even though we admit there are thermophiles in milk, we can not tell in advance what their action will be or how quickly they will act, without actual data on the subject. For this reason we wish briefly to report the results of a few experiments.

As early as 1867 Muller (4) while studying the influence of temperature on milk souring found that milk held at 50°C. (122°F.) became sour and appeared greenish-yellow, the same as at 35°C. (98°F.). He came to the conclusion, however, that at 50°C. (122°F.) the souring appeared to be due to a different kind of fermentation from that at lower temperature, and that it should be investigated. Leichmann (3) in 1894 found that milk coagulated after twelve to fifteen hours when held at 50°C.(122°F.) and that a fine coagulum appeared. He pointed out that this fermentation was not due to the ordinary milk-souring organism.

These fermentations were undoubtedly due to thermophiles, which under favorable conditions may develop and play an important rôle in the changes that take place in the milk and

dairy products. Jensen (2) has recognized this fact and recommended that skimmed milk be cooled after pasteurization at the creamery, instead of being returned hot to the producer, because changes were produced in it by the growth of thermophiles. Recent studies by the authors have shown how Lactobacillus thermophilus grows in the milk at high temperatures and how it is related to pin-point colonies and high counts in pasteurized milk.

This knowledge of the ability of bacteria to grow in milk at high temperatures clearly indicates that difficulties may be expected in substituting heat for cold in the transportation of milk.

The idea of keeping milk hot during shipment is by no means a new one. Bernstein (5) in 1893 advanced the idea that instead of refrigerating milk it could be heated to about 70°C. (158°F.) and kept at that temperature during transportation. His general plan, which may be of interest, was as follows:

At suitable stations along the railroad he planned collecting stations. There milk was to be tested and heated to the desired temperature for transportation.

For transport, differently constructed railroad cars were to be used according to the distance of shipment.

For long distances, tank cars were to be used, consisting of long cylindrical tanks surrounded by a hot-water jacket. The temperature was to be kept constant by a hot-air oven and the milk kept in motion by an electric motor which was to receive its current from a storage battery.

For short distances, heating could be omitted because of the large volume of heated milk, surrounded by insulation, which would change temperature only slowly.

Upon arrival at its destination, the milk was to be cooled rapidly to a very low temperature and then supplied directly to distributors in closed vessels.

Bernstein made one experimental run from Hamburg to Berlin, a ten-hour trip, with a small experimental apparatus, and says the milk was found to be excellent upon its arrival. Probably difficulties were encountered, as one might expect, for the method has not been used commercially so far as is known.

It is true, however, that the heating of milk in an evaporated form has been resorted to in some instances in this country for short shipments when refrigeration has not been easily available.

EXPERIMENTAL RESULTS

The authors have made a number of experiments in which fresh milk was heated and held at various temperatures and examined at frequent intervals up to twenty-four hours.

One liter of milk was used in each experiment which was flashed to the desired temperature, then placed in a sterilized glass museum jar of 1.5 liters capacity. This jar was covered with a heavy brass top which fitted on to the ground-glass top of the jar so that evaporation was practically eliminated. A propeller shaft extended through the brass top into the milk and this propeller was rotated at a speed just sufficient to prevent the melted butter fat from rising to the surface. The jar of milk was held in a water bath and the temperature kept constant at the desired point.

In a preliminary experiment with milk held at 60°C. (140°F.) it was found that after twenty-four hours the acidity had increased and the milk was coagulated to a very fine curd. This indicated that thermophilic bacteria were present, and therefore in most of the experiments bacteria counts were made at two temperatures.

It will be apparent from table 1 that milk can not be held at any temperature from 50°C. (122°F.) to 60°C. (140°F.) for twenty-four hours without undergoing changes produced by bacteria growth. When held at 50°C. (122°F.) a rennet curd is likely to develop with some acidity as well. When the milk was not coagulated and appeared normal, it had a strong bitter taste, clearly indicating proteolysis with peptone formation. At 60°C. (140°F.) the fermentation was more strictly of the acid type. Even though the acidity did not develop to a point which might be expected to be required to coagulate milk, coagulation usually occurred after twenty-four hours holding. However, it must not be forgotten in this connection that the effect of acid is increased by the long heating at high temperatures.

TABLE 1

Bacteria counts of milk held at different temperatures for different periods

TEST NUMBER	MILK HOLDING TEMPERATURE	RAW MILK		PLATE INCUBATION TEMPERATURE	SECOND EXAMINATION		THIRD EXAMINATION, AFTER TWENTY-FOUR HOURS		Remarks.
		Bacteria per cubic centimeter	Per cent acidity		Hours held	Bacteria per cubic centimeter	Bacteria per cubic centimeter	Per cent acidity	
1	50°C. (122°F.)	62,000	0.16	30°C.			1,770,000	0.38	Coagulated, (rennet)
2	50°C. (122°F.)							0.24	Not coagulated
3	55°C. (131°F.)	2,700	0.17	30°C.	4	900	24,700	0.34	Not coagulted
4	55°C. (131°F.)								Coagulated
5	60°C. (140°F.)	91,000	0.19	37°C.	6	10	70	0.41	Sour, not coagulated
	60°C. (140°F.)	5–1/100 cc.		55°C.	6	0–1/100 cc.	3,100,000		
6	60°C. (140°F.)	17,700	0.17	30°C.			3,100	0.27	Not coagulated
	60°C. (140°F.)	900		55°C.			5,340,000		
7	60°C. (140°F.)	42,000	0.17	30°C.	8	900	3,400	0.30	Very fine curd
	60°C. (140°F.)	0–1/1000 cc.		55°C.	8	75,000	440,000		
8	60°C. (140°F.)	60,000	0.18	37°C.	6	50		0.27	Coagulated, whey
	60°C. (140°F.)	20		60°C.	6	1,730*			
9	60°C. (140°F.)	25,700	0.17	37°C.	4	70	280,000	0.32	Coagulated, fine curd
	60°C. (140°F.)	420		60°C.	4	90	728,000		

* Also a large number of pinpoint colonies.

Further study of the results reveals the fact that the bacteria count made at 30°C. (86°F.) and 37.7°C. (100°F.) usually showed low numbers after twenty-four hours while the counts made by incubation at 55°C. (131°F.) and 60°C. (140°F.) showed high numbers. This, of course, might be expected, since we are dealing with bacteria which grow at high temperatures.

A study of a few cultures isolated from milk held for twenty-four hours at temperatures ranging from 50°C. (122°F.) to 60°C. (140°F.) showed two general types. One consisted of spore-forming peptonizing and rennet-producing bacteria which developed most rapidly from 40°C. (104°F.) to 50°C. (122°F.). The other type consisted of weak acid-producing bacilli resembling Lactobacillus thermophilus. These organisms grew more rapidly at temperatures from 50°C. (122°F.) to 60°C. (140°F.), which probably explained the difference in the type of fermentation observed in milk held at 50°C. (122°F.) and 60°C. (140°F.).

From these results it is evident that milk can not be held at high temperatures for a period of twenty-four hours without undergoing changes which would make it valueless for commercial purposes. Therefore, for this holding period heat can not replace refrigeration.

It is possible to conceive conditions where the use of heat in place of cold might be practicable for short shipment distances, provided the period of holding is less than twenty-four hours. As an example of such a condition, the collection of milk in tanks on automobile trucks where it can be heated to and held at a desired temperature by hot exhaust gases from the engine may be mentioned. Here the holding period during transportation would only be a few hours. Whether or not such a plan is feasible will depend upon a number of things: First, the growth of thermophilic bacteria during holding periods shorter than twenty-four hours; second, the physical and chemical changes produced, and third, the use which will be made of the milk. We do not have complete data on these points, but that which is available may be of interest.

Referring again to table 1 it will be noted that a number of lots of milk were examined for bacteria after being held from four

to eight hours. Apparently the thermophilic bacteria had not developed to any great extent during these holding periods, although in one experiment where milk was held for eight hours at 60°C. (140°F.) the thermophiles increased to 75,000 per cubic centimeter. Milk to be used for manufacturing purposes such as butter making could perhaps be shipped hot if the transportation period did not exceed six hours. In suggesting this possibility we are considering only the bacteria changes. It remains to be determined whether or not the effect of long heating would show an effect on the butter made from it.

We are inclined to believe that the heating of milk during transportation even for short periods is not practical if the milk is to be consumed in the fluid state.

INFLUENCE OF LONG HEATING ON THE CREAM VOLUME

In discussing the feasibility of transporting milk, in a hot condition, which is to be consumed in a fluid state, the question of the effect on the cream volume is of primary importance.

A number of experiments were made to determine this effect and the results are shown in table 2. The milk used was fresh milk, less than five hours old. It was flashed to the desired temperature, then held for the desired time, and agitated during the holding period. For the determination of the percentage of cream volume the method described by Harding (1) was used.

While the experiments were only a few in number they indicate what the probable effect of long heating will be. Heating for six hours at temperatures of 50°C. (122°F.) and 55°C. (131°F.) apparently had no effect on the cream volume. After twenty-four hours at 50°C. (122°F.) the cream volume was not affected in one experiment, although in the other it was reduced nearly 50 per cent.

When milk was held at 60°C. (140°F.) variable results were obtained with short holding periods, and some reduction was observed after three hours heating. No measurements could be obtained after twenty-four hours holding, since the milk was always coagulated. When the milk was heated to 62.8°C.

(145°F.) and held for one hour the cream volume was not changed, although it was reduced after two hours holding.

The effect of long heating on the cream volume causes another complication in the transportation of hot milk which is to be consumed in the fluid state.

TABLE 2

Effect of temperatures and different holding periods on the cream volume

TEST NUMBER	HOLDING TEMPERATURE	FAT IN MILK	CREAM VOLUME IN RAW MILK	CREAM VOLUME IN MILK AFTER DIFFERENT HOLDING PERIODS					
				½ hour	1 hour	3 hours	4 hours	6 hours	24 hours
		per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
1	50°C. (122°F.)		15.0	15.0				16.0	8.0
2	50°C. (122°F.)	3.5	13.5	12.5				13.5	14.0
3	55°C. (131°F.)		14.0	14.0				14.5	
4	55°C. (131°F.)		12.5	12.5				13.0	
5	60°C. (140°F.)	3.4	14.5		17.5	15.2		12.2	
6	60°C. (140°F.)	4.1	18.5	19.5			17.5	16.5	
8	60°C. (140°F.)	3.2	14.0	14.0				8.5	
8	60°C. (140°F.)	2.8	13.0	13.0		10.0		10.0	
9	62.8°C. (145°F.)		15.5	15.5	15.5* 12.0†	7.0		5.5	

* Held one hour.

† Held two hours.

SUMMARY

It is shown that the growth of thermophilic bacteria complicates the scheme for transporting milk in a hot condition.

Another factor is the effect on the physical condition of the milk.

Milk held at temperatures ranging from 50°C. (122°F.) to 60°C. (140°F.) for a period of twenty-four hours is usually coagulated. The type of fermentation at 50° C. (122°F.) appears to be different from that at 60°C. (140°F.).

The results do not indicate that heat can be used as a substitute for cold during periods of transportation. This is particularly true with milk for direct consumption.

It may be feasible to ship milk in a hot condition under conditions where milk is to be used for the manufacture of butter and where the transportation period is not over a few hours. Further study of this problem is however required.

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THE WIDE DISTRIBUTION OF ROPY MILK ORGANISMS IN CITY MILK SUPPLIES

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The occurrence of the viscid condition in milk, commonly called ropy milk, constitutes one of the most serious causes of complaints with which milk dealers have to contend. Ropy milk is harmless but the viscid, slimy consistency is not familiar to the consumer, and the detection of the condition causes loss of trade. Ropy milk is more common in the raw product but occurs in pasteurized milk and its repression calls for vigilance on the part of the employees of establishments marketing this product.

EARLY OBSERVATIONS

In 1898, the writer began the study of a series of outbreaks of ropy milk, and embodied these observations in two bulletins. The outstanding facts observed were: the relation of Bacterium lactis viscosum (Adametz) to the trouble, the ability of the organism to grow at unusually low temperatures where acid producing organisms are relatively inactive, the relation of faulty scalding of milk utensils to the continuance of the trouble and the frequent occurrence of the organisms in air and floor dust. The prevalence of the organism in water used for cooling was constantly noted in the milk plants studied.

The distribution of ropy milk organisms was first studied in two establishments at a time when the consumers were complaining of the product. These organisms were found in improperly scalded utensils, in the water of can cooling tanks but not in the milk as it came from the farms. During the investigation of another plant, ropy milk was detected in milk cooled in ice water, although the condition was not recognized by the consumers. Ropy milk organisms were also found in the ice

water of the cooling vat, in certain utensils, in floor dust, and in samples of sterile milk exposed to contamination from the air. Infection was likewise found in water as delivered from a hose, but not in water from other sources. The ropy milk organisms were also found in unscalded utensils at the farm.

These early observations dealt with the occurrence of the trouble in small retail establishments provided with much simpler equipment than used at present and at a time long before modern pasteurization was practised.

RECENT WORK

There has come to notice but one piece of work, that by Harding and Prucha (3) concerning ropy milk as occurring in modern milk plants. These writers studied outbreaks of ropy milk in the bottled product of several pasteurizing plants. They showed that the accepted pasteurizing process kills the ropy milk organisms. Nevertheless, the outbreak was repressed only by the exercise of great vigilance due to the numerous opportunities for re-contamination.

The most recent summary of the strictly bacteriological phases of the subject is embodied in a bulletin by Buchanan and Hammer (4) who include an extensive bibliography.

METHODS

In connection with his earlier work on ropy milk the writer developed the method of searching for ropy milk organisms by exposing sterile milk to contamination in various suspected utensils. The method has likewise proven of value in the most recent studies. Ordinary tubes of sterile milk were prepared. When conditions were suitable the milk was poured into the utensil, and immediately as much as possible was recovered. In other cases suspected material was added to the tubes. The infected samples of milk were then held at about 55°F. and examined several days later. This temperature was selected because ropy milk organisms could grow here without much competition from the acid producing organisms. It was also

preferable to anything higher because it commonly occurred in the available ice-cooled refrigerator.

After standing a few days, the ropy milk infection may be detected by the viscid condition as revealed by the use of the platinum loop. The layer of cream is a disadvantage in making this test as the physical characteristics of cream mask the lower degrees of viscosity. Skimmed milk has been used in all the recent work. In this material very slight ropiness is revealed by the gossamer-like thread of milk connecting the loop with the surface of the fluid. In case of slight viscosity, a fiber of cotton adhering to the loop may cause erroneous conclusions. In the advanced stages, viscosity is such that threads several feet long may be drawn from the surface of the milk.

Similarly, the use of low temperature incubation enables one to take samples of milk at various stages in its course from the cow to the consumer and locate the first point at which ropy milk infection is imparted.

While the general range of temperature favorable to the development of ropiness in milk is known, lack of suitable apparatus has prevented the determination of the exact optimum temperature for the development of this condition in milk containing a mixed flora.

For the purposes of the work in hand, 60°F. has been assumed to be the favorable temperature and various devices have been employed to secure this. We know that 68°F. the lactic acid organisms overgrow the ropy milk organisms and effort has been made to keep at least 5° below this point. In hot weather, samples have been kept in a refrigerator at about 55°F. and such samples have developed ropiness in a period varying from four to seven days. During the period in the autumn when the temperature of the city water supply was about 60° this water was utilized for securing a constant temperature and results were obtainable in two or three days. In winter, the cooler parts of heated rooms have been employed.

PHASES OF PROBLEMS NOT STUDIED

The present work has not included the isolation of strains of bacteria and their study on various media. The alteration of the physical characteristics of the milk when it became viscid at a temperature of 55° to 60°F. was deemed sufficient for the purposes of the study of the phase of the subject in hand. Thus, the ropy milk to which the writer refers, is that which occurs at the lower temperatures and does not concern those organisms producing viscosity at higher temperatures. The study of strains is an attractive field which has not been entered upon in the present study.

NORMAL DISTRIBUTIONS OF ROPY MILK ORGANISMS

During the past summer, autumn and early winter, opportunity has been afforded to carry out a study of the occurrence of ropy milk organisms in a city milk supply in the absence of an outbreak of ropy milk. The dealer who furnished the facilities for the study carried on an extensive trade in market milk pasteurized in a number of plants. During the period covered by my observations (August 1 to the end of the year) no complaints of ropy milk were received from the consumers. Routine examinations were made weekly by the company's laboratory staff of samples of milk from the various bottling plants. These were kept at a temperature approximately 55°F. and examined with a platinum loop after four days. Under such conditions of time and temperature occasional samples became slightly but distinctly ropy. The conditions were favorable for a study of the occurrence of ropy milk bacteria in the milk supplied these plants under normal conditions as contrasted with a period when ropy milk was causing complaints.

ROPY MILK DELIVERED BY PATRONS

The occurrence of ropy milk organisms in samples of milk from each producer was studied in three plants. Milk was collected in half pint bottles which were fresh from exposure to 200°F. for ten minutes and which had been kept inverted in

racks until used. As each can of a patron's milk was dumped, a small portion was collected in a bottle. The resulting sample was a rough composite of the patron's milk, surely containing representation of both morning's and evening's milk. Each bottle was covered with the ordinary bottle cap, upon which the identification number was written.

The samples were stored in bottle cases in the cool room of the plant for four days at a temperature not exceeding 55°F.

The results obtained from a study of the milk of all of the patrons at three shipping stations, showing the proportion of these which were bringing ropy milk germs are shown in table 1.

Thus 13 per cent of samples from 307 patrons held at a low temperature became ropy in four days. It is believed that the temperature employed (40 to 45°F.) was too low for encouraging

TABLE 1

Development of ropy milk in patron's samples

PLANT	NUMBER PATRONS	NUMBER ROPY	PER CENT ROPY
1	70	11	15
2	91	14	15
3	146	17	11
Total.....	307	42	13

the development of the maximum number of ropy samples within the time limit employed. With a higher temperature a higher percentage of ropiness doubtless would have been observed.

The results indicate that the delivery to these plants of milk contaminated with ropy milk organisms is a very common occurrence.

ROPY MILK AND THE WILLMAN HOLDER

The frequency of the detection of ropy milk organisms in the raw milk suggested the desirability of studying the pasteurizing and bottling processes in relation to ropy milk. The milk was held at approximately 144° for thirty minutes in a Willman holder.

For purposes of studying the problem in hand, the condition of the milk at various stages of its passage through the plant may be designated as follows: (1) raw, as it enters clarifier; (2) heated, or short exposure in heating coils; (3) held, that is after holding 30 minutes; (4) cooled, sampled when leaving cooler and (5) sampled from bottling machine.

Six different sets of samples representing a like number of days runs in three pasteurizing plants were collected. It is not the purpose here to discuss these tests in detail, but only to present data obtained regarding the presence of ropy milk organisms in the milk at various stages.

The prevalence of ropy milk contamination in samples of raw milk is shown by its detection in 36 out of 40 samples taken during these tests. Examination of 32 samples of the momentarily heated milk showed that 9 samples were ropy and 23 not ropy. This is in accordance with our knowledge of the thermal peath point of the organism as shown by Harding and Prucha. Samples of the milk after holding thirty minutes were taken in 24 instances and none became ropy. This result confirms our belief that pastuerization kills the organism. Of the cooled milk, 35 samples were taken and 6 became ropy. Of 44 samples from the bottling machine 18 became ropy. The results obtained from both cooled and bottled milk indicate re-contamination of the product subsequent to pasteurization. Certain runs were so nearly perfect that it may be assumed that such contamination is preventable.

ROPY MILK CONTAMINATION OF UTENSILS

Search for ropy milk organisms by the use of skimmed milk heretofore described, has been made in several plants. Positive results were obtained with great frequency in samples exposed to contamination in any utensil which has been washed but not scalded. Among such are sanitary piping valves, end caps for piping, coolers and the like. The water remaining in such apparatus after washing is found to carry ropy milk organisms. Among pieces of apparatus less apt to be regularly washed and scalded are sample dippers and can stirrers which give a high per-

centage of positive results. The milky water standing on the floor of plants is highly contaminated with the organisms. Brushes of all kinds are in the same class as demonstrated by placing a few bristles in skimmed milk. Samples contaminated from water obtained from a steam hose gave positive results in several cases, but no water supply has been definitely proven to be a source of introduction of organisms into a plant.

In one plant a positive result was obtained by adding dust from a window sill to skimmed milk. In the same establishment condensation water from the outside of a pipe conveying cool milk was shown to contain ropy milk organisms. The condensation water collecting on the inside of the lids of vat pasteurizers during cooling, has also been found to be infected with ropy milk organisms. Examination of a series of returned, unwashed milk bottles by means of the skimmed milk test revealed a high percentage of bottles harboring ropy milk organisms.

Ropy milk organisms may be regarded as so common as to constitute an ever present source of a possibly serious outbreak. The routine methods of scalding utensils in well managed plants are ordinarily sufficient to prevent the dreaded recognition by customers within the ordinary time limit available. Constant vigilance on the part of employees is necessary to prevent the ropy milk.

GENERAL DISCUSSION

The occurrence of ropy milk to a degree sufficient to cause complaint by the purchasers, seems to be dependent upon several factors: (1) the presence of the necessary germ; (2) suitable temperature for multiplication; (3) sufficient time for growth to a recognizable degree at the temperature to which the milk is subjected.

The foregoing observations indicate that at least slight contamination occurs with a frequency not heretofore recognized.

The facilities for holding milk at a temperature below 55°F. at the disposal of distributors, induce a temperature sufficiently low to hold the multiplication of the ropy milk organisms below the danger point. Household refrigeration in the summer by

means of ice, and in winter by means of outdoor temperature, prevents the appearance of ropiness. Time and temperature conditions in the main, are unfavorable to the occurrence of ropy milk.

These controlling factors may vary at any time and result in the occurrence of ropiness within the period ordinarily elapsing before milk is consumed. In this connection, it may be noted that large dealers observe that complaints of ropy milk are most apt to be made in the spring and autumn. In the spring, there is an interval after out-door refrigeration fails to be effective and before the use of ice begins, while in the autumn, the conditions are reversed. During these two periods the milk at the home is ordinarily held at about 60°F. In consequence of these temperature conditions, ropy milk is more frequently observed by consumers in spring and autumn.

The idea of locating the original source of contamination leading to specific outbreaks of ropy milk pervades the earlier discussions of this subject. This reflects the belief formerly held by all of us, that while ropy milk organisms become widely distributed in utensils, in milk, and in places contaminated by ropy milk, that such distribution was temporary. Knowledge of the wide distribution of the organisms during outbreaks was general and stimulated the application of such measures as general disinfection of stables, milk houses and floors.

The facts now available warrant our regarding ropiness as a common change in milk ordinarily repressed by the maintenance of conditions unfavorable to its prompt development. Just as the development of sour milk organisms at higher temperature are controlled by time and temperature, so the development of ropy milk organisms is ordinarily restricted by the same factors.

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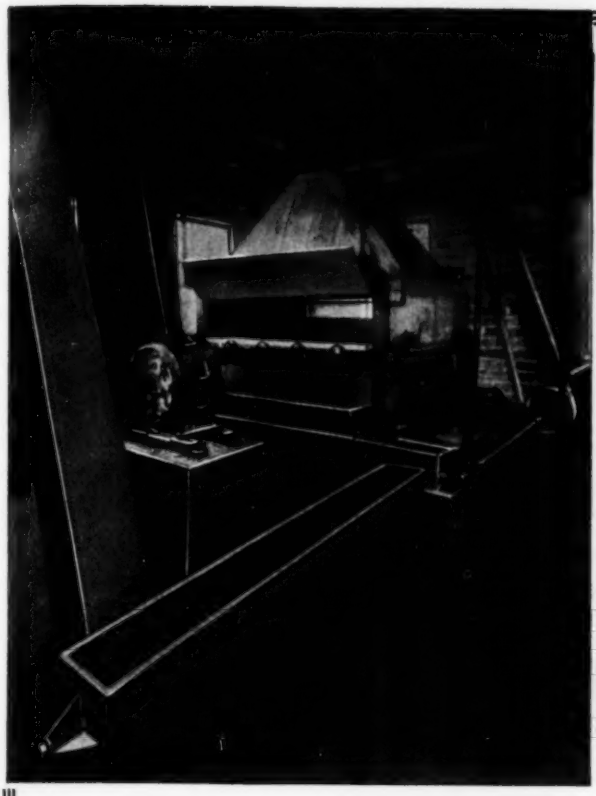

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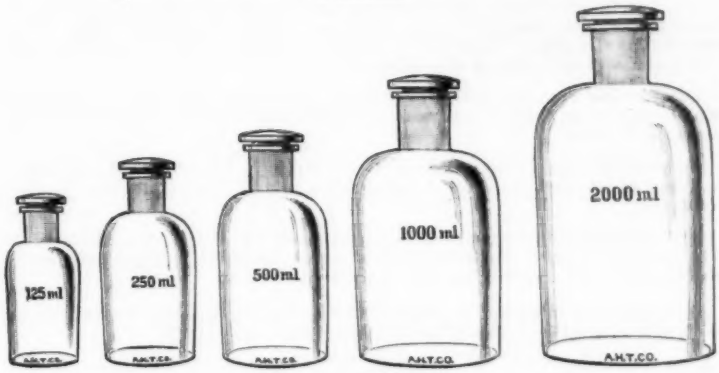

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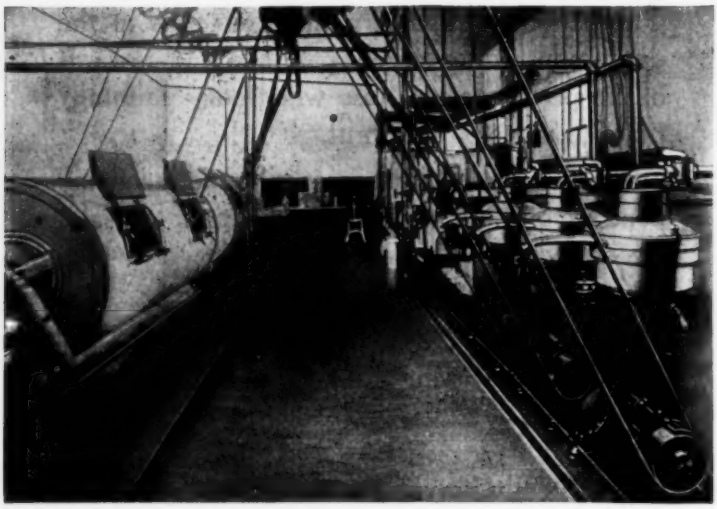

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